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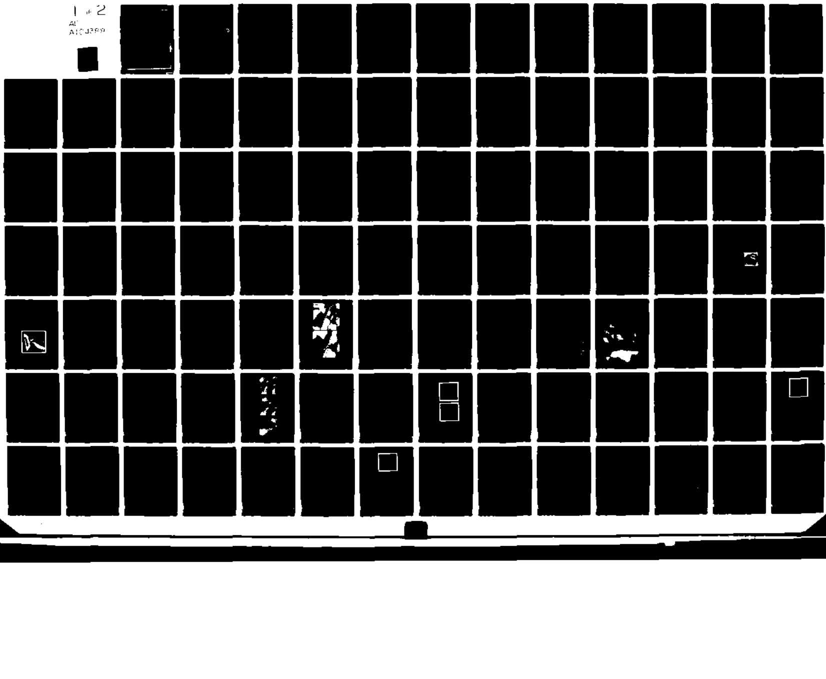

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CONCEPTUAL DESIGN OF A COMPUTER-GENERATED TOPOGRAPHIC DISPLAY SYSTEM TO AID MISSION PLANNING AND MISSION CONDUCT BY ARMY AVIATORS

Submitted to:

DEPARTMENT OF THE ARMY
U.S. ARMY RESEARCH INSTITUTE FOR THE
BEHAVIORAL AND SOCIAL SCIENCES
Field Unit (PERI-OA)
Fort Rucker, Alabama

and

ADVANCED SYSTEMS DIVISION
U.S. ARMY AVIONICS R&D ACTIVITY
Fort Monmouth, New Jersey

June 1981

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CONCEPTUAL DESIGN OF A COMPUTER-GENERATED TOPOGRAPHIC DISPLAY SYSTEM TO AID MISSION PLANNING AND MISSION CONDUCT BY ARMY AVIATORS

Steven P. Rogers

Submitted to:

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This report describes the requirements for a computer-generated topographic display for use by Army aviators during performance of mission-planning and in-flight tasks, and presents a conceptual design for such a system. Section I of the report describes the background leading up to the conduct of the project the project objective, the project approach, and the organization of the report. Section II of the report provides a background in the missions, organization, and procedures of Army aviation units for readers not thoroughly familiar with (Continued on reverse side)

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20 ABSTRACT (Cont.)

these topics. Much of the information in this section is based on data from in-depth interviews with aviators of the 101st Airborne Division. Section III of the report describes the configuration and operation of the recommended computer-generated topographic display system. The general philosophy guiding the conceptual design is discussed, followed by a description of the system components and their functions. Extensive descriptions of the interactive, multi-function, control-display units are provided, accompanied by summaries of the aviator requirements, present deficiencies, and computer capabilities that led to the incorporation of the various special features of the system.

ACKNOWLEDGMENTS

One of the most critical elements of a design study such as this one is an understanding of the system users' requirements. As a result, there is no substitute for in-depth interviews with experienced personnel. The author is deeply indebted to the following aviators for their contributions of time and expertise:

PARTICIPANTS FROM THE 101ST AIRBORNE DIVISION:

CPT Rusty Davis	OPNS Officer, 101st ABN DIV
CPT Michael Huffman	Asst S-3, 101st AVN GP
CPT Steven Yuhas	Asst S-3, 101st AVN GP
CW3 Charles Graham	Asst FLT OPNS Officer, 101st AVN GP
LTC Barry Sottak	Commander, 101st AVN BN
MAJ Charles Cook	Commander, D Co. 101st AVN BN
CPT Robert Gunning	FLT OPNS Officer, D Co., 101st AVN BN
CPT John Sapienza	PLT LDR, 1st PLT, B Co., 101st AVN BN
CW3 Marc Moller	Standardization I.P. 158th AVN BN
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LTC Robert Young	Commander, 2nd SQDN, 17th AIR CAV
CPT Michael Stewart	S-3, 2nd SQDN, 17th AIR CAV
MAJ Ken Wilson	Commander, A TRP, 2nd-17th
CPT Mark Waldron	PLT LDR, Aeroweapons PLT, A TRP, 2nd-17th
CPT Benny Steagall	PLT LDR, Aeroscout PLT, A TRP, 2nd-17th
LT John Russell	PLT LDR, Aerorifle PLT, A TRP, 2nd-17th
CW2 Michael Chase	Standardization I.P., Aeroscout PLT, A TRP, 2nd-17th

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CW4 Hugh Leatherwood	Instructor, Aviation Subjects Branch

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CPT William L. Wimbish	Executive Officer, D TRP, 2nd-1st
CPT Jeffrey W. McClure	Operations Officer, D TRP, 2nd-1st
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CPT Steven W. Stiles	CDR, ASCT PLT, B TRP, 7th-17th

Special thanks are due to MAJ Gordon Rogers, Asst. Chief, ARI Field Unit, Fort Rucker, for making the initial arrangements for these interviews.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure		Page

SECTION I

INTRODUCTION

This report describes the requirements for a computer-generated topographic display for use by Army aviators during performance of mission-planning and in-flight tasks and presents a conceptual design for such a system. This project was conducted under Contract DAHC19-78-C-0012, Modification No. P00005, for the U. S. Army Research Institute for the Behavioral and Social Sciences and for the Advanced Systems Division of the U. S. Army Avionics Research and Development Activity.

This section of the report describes the background leading up to the conduct of this project, the project objectives, the project approach, and the organization of the report.

BACKGROUND

ARMY AVIATION TASKS

A scant 30 years ago, the helicopter was deemed useful for little more than medical evacuation of wounded foot soldiers. Today, helicopters are an integral component of the combined arms team and perform a great variety of tasks. Army aviators must be prepared to enhance the ground commander's capabilities in one or more of the five functions of land combat: firepower, mobility, intelligence, command and control, and combat service support.

- **Firepower.** Army aviation units assist the commander in exploitation of firepower by delivering area and point target fire, by observing and adjusting artillery fire, by transporting artillery and antitank teams, and by providing ammunition resupply.

- **Mobility.** Helicopters are ideally suited for rapid movement over obstacles in order to concentrate forçes for decisive combat power, and to promptly disperse these forces and permit their redeployment in other critical sectors. This rapid mobility also permits the commander to surprise the enemy and exploit the enemy's lack of preparedness.

- **Intelligence.** Army aircraft have an unequaled capability to perform reconnaissance over a wide area, providing current intelligence regarding weather, terrain, and enemy disposition. Where vegetation limits aerial observation, ground reconnaissance teams may be transported by helicopter to collect the required information quickly.

- **Command and Control.** Army aviation assists in commanding and controlling highly mobile forces operating over broad areas by permitting commanders to study the terrain while maintaining contact with superior and subordinate commanders, and by permitting the commander to move rapidly to the places he is most urgently needed.

- **Combat Service Support.** Army helicopters provide logistical lifelines for friendly elements dispersed across vast areas, often providing the only possible means of resupply of fuel, ordinance, and repair parts as well as evacuation of critical weapons and systems to repair facilities.

The functions of Army aviation described above require the performance of an impressive array of diverse missions. The missions required depend upon the aviation unit type, the combat arm that the aviation unit serves, the aircraft type, and the specific tactical situation. Thus, the potential missions of Army aviation are countless. A common theme in nearly all of these missions, however, is the requirement for terrain flight.

Terrain Flight

Terrain flight is the tactic of degrading the enemy's ability to detect the aircraft by using landforms and vegetation for cover and concealment. This tactic requires flight close to the earth's surface and includes low-level, contour, and nap-of-the-earth (NOE) techniques. Low-level flight generally employs a constant heading, altitude, and airspeed. Contour flight is conducted in very close proximity to the ground and requires altitude changes to conform to the contour of the earth, while maintaining a generally constant heading. NOE flight is flight as close to the earth's surface as vegetation and obstacles will permit, varying course, airspeed, and altitude in order to take maximum advantage of the cover and concealment offered by terrain, vegetation, and man-made features. In practice, the aviator may use a combination of these three techniques during a single mission. The most important determinants of flight techniques are the enemy situation and the availability of masking terrain. It is critical that the aviator be aware of the

positions and altitudes at which masking is or is not available. Flying unmasked sharply reduces survival probability in the high-threat environment. On the other hand, unnecessary NOE flight is inefficient because more sorties can be flown or greater distances covered in a given period using contour or low-level flight. Furthermore, high altitudes offer a greater margin of safety in dealing with aircraft emergencies and hazard avoidance.

Geographic Orientation

Whatever the combat task or flight technique, the Army aviator must be able to maintain his geographic orientation at all times. Aviators must be able to plan and execute their missions precisely in both time and space and relate their momentary position to their planned route and to the movements of other friendly ground and air forces. In the critical timing of events on the modern battlefield, disorientation is tantamount to mission failure. As a minimum standard, Army aviators are expected to navigate to an accuracy of 100 meters at all times (FM 1-1). Furthermore, aviators are expected to navigate in unfamiliar terrain, around-the-clock, and in adverse weather conditions.

Descent to NOE flight levels greatly increases the likelihood of geographic disorientation due to the aviator's limited view of checkpoint features useful in navigation. While NOE flight serves to mask the enemy's view of the helicopter, it often masks the aviator's view of potential checkpoints. The view of the surrounding terrain may be limited to features within 100 meters of the aircraft. Features often cannot be seen in their entirety, and the extremely low angle of view increases the difficulty of determining the contours of visible landforms.

Both anecdotal evidence and controlled field tests have indicated that the percentage of NOE sorties in which the aviators experience no navigation problems and remain well oriented throughout the flight is exceedingly small. In an early study by Thomas (1964), aviators were able to navigate a 6-km course only 48% of the time without becoming disoriented. In a Canadian test (Lewis & de la Riviere, 1962), aviators were able to reach the designated end points of short courses only 61% of the time. In a more recent experiment (USACDEC, 1972), major course

deviations (500-2000 meters) occurred in half of the 12 30-km course attempts by Cobras, and only two crews navigated the entire course without missing checkpoints, circling, doubling back, or experiencing other navigational difficulties. In another recent test (Fineberg, Meister, & Farrell, 1975), 35 Army aviators flew NOE Missions in a series of 279 test flights. The results of this experiment indicated that the probability of successfully acquiring both the initial point (IP) and a subsequent landing zone (LZ) was .65.

Mission Planning

The results of laboratory studies of the accuracy of geographic orientation by Army aviators (Rogers and Cross, 1978, 1980) are in agreement with the field tests, and suggest that the navigation problems are rooted in the difficulty of the map interpretation and terrain analysis tasks. Such findings suggest that the aviators must also experience great difficulty in the extensive mission-planning tasks required for each mission. The successful accomplishment of many of these tasks depends heavily upon the aviator's ability to extract voluminous information from maps. For example, the aviator must study and visualize the overall situation and topography; select engagement points, observation points, or landing zones; determine primary and alternate (masked) routes of flight; select air control points, checkpoints, and barrier features; and determine flight modes, altitudes, speeds, and durations. Each of these activities places an onerous information compilation and processing burden upon the aviator, and omissions or errors might well prove to be disastrous. Although previous map display systems have been designed primarily for assisting in navigation, it would appear that the potential contribution of a map display might well be greatest in aiding the performance of mission-planning and tactical decision-making tasks.

PREVIOUS MAP DISPLAY SYSTEMS

Early attempts to overcome navigation problems included a number of display devices--primarily moving map displays--driven by the navigation sensors available in aircraft. Taylor (1975) listed six potential advantages of moving-map displays:

- They may reduce navigation workload and head-down time in the cockpit by monitoring geographical position.
- They may provide a method for cross-checking navigation systems (INS, doppler, radar, etc.).
- They may offer a compatible means of interacting with navigation computer systems.
- They may permit storage of large areas of mapping at a variety of scales.
- They may be able to display navigation information (e.g., distance, time, and bearing to destination) as well as topographic information.
- They may assist the aviator in anticipating and recognizing checkpoints.

The earliest moving map displays developed were "direct view" displays employing strip maps which moved on rollers. An indicator was displaced to show present position on the cross-track axis. Related developments employed moving cross-wires to indicate the aircraft's position on stationary maps. The primary disadvantages of direct view displays are: their map storage capacities are small, an impractical amount of time is required to prepare the strip charts, they do not display heading information, and the orientation of the charts is fixed. Furthermore, Army aviators very seldom fly in the limited corridors suited to the use of strip charts, and rapidly fly across areas portrayable on fixed charts of the size suitable for direct view displays given the large map scale required for NOE flight.

Another form of moving map device is the projected map display (PMD), which optically projects photographs of existing paper maps onto a viewing screen. PMD's have a number of advantages over hand-held maps and direct-view map displays, but unlike either of these aids, they cannot be annotated. The importance of map annotations to the Army aviator cannot be overstated. It must be possible to mark route plans and tactical information on the map if a display is to be acceptable for use in Army aviation. A second disadvantage of the PMD is its dependence upon the availability of conventional maps. The large-scale maps required for use in Army aviation are not available for large areas of the world.

COMPUTER-GENERATED SYSTEMS

A computer-generated topographic display (CGTD) can provide all of the advantages of the earlier moving map displays and add some revolutionary capabilities. A CGTD system will provide not only an enhanced navigation capability, but also a combination of dramatic improvements in cartographic support, map information content, map-oriented computations, and aviator-map interactions. Some of the potential advantages of the CGTD are discussed below.

The single most important advantage of the CGTD over paper maps or projected map displays is its promise of truly comprehensive and rapid response cartographic support. NOE flight requires the use of large-scale maps (1:50,000 or larger). The smaller scale maps (such as 1:250,000 and 1:500,000), which are designed for conventional flight, do not portray sufficient detail for NOE navigation. Only a very small percentage of the earth's surface is currently mapped in large scale and, in the event that a conflict arose in an unmapped area, it could take more than a year to develop conventional topographic maps. Even photo-base maps could require a month or more for preparation. In contrast, it is feasible to obtain the data required to support computer-generated display systems in a matter of hours.

A second advantage of the CGTD is its potential capability for providing operator control of the content of the displayed information. Many of the problems in using contemporary 1:50,000-scale topographic maps stems from the fact that maps were designed to fulfill the requirements of all branches of the Army. The result is a compromise product that is densely packed with data but is not optimal for any single user. The Army aviator, because of his variety of roles, may need many different types of information on different missions or in different phases of a single mission, yet map clutter must be avoided to the greatest extent possible. Aviators using a computer-generated system can select the information that is needed to provide a map optimal for the momentary situation. Aviators can be given control of the classes of information that are displayed (vegetation, hydrography, etc.) and the specific features of a given class to be portrayed (deciduous trees, perennial streams, etc.). In addition, map scale and contour interval could be changed at will to tailor the map to the aviator's changing requirements.

A third advantage of the CGTD over conventional map products is its powerful computational capability. For example, the CGTD can be used to:

- Show the general lay of the land by use of shaded elevation bands to indicate high and low areas.
- Present a shaded "relief map" enhanced by contour lines.
- Display the areas masked from visual or radar observation given known or likely enemy positions.
- Construct oblique, perspective views of terrain to familiarize the aviator with the "lay of the land".
- Perform navigational computations pertaining to airspeed, elapsed time, or wind vector considerations over a given flight route.
- Interact with a terrain correlation navigation system similar to that used in the cruise missile, which is small, lightweight, accurate in all weather, self-contained, and essentially invulnerable to countermeasures.

A fourth advantage of the CGTD is that it offers a truly interactive system. The aviator can enter information such as map annotations, coordinates of objectives, planned routes, and so forth. These items of information can then be selected at will, and used in the computations described above. Furthermore, the "intelligent" nature of the system can permit its interrogation by the aviator to determine characteristics of the portrayed features, such as height of forests, speed of streams, and so forth. The interactive nature of the CGTD can remove some of the natural limits to the aviator's decision-making capabilities and permit him to rapidly solve problems of previously unthinkable complexity.

PROJECT OBJECTIVES

The general objective of this project was to develop a conceptual design for a computer-generated topographic display system for use by Army aviators. The specific objectives were to:

- Define functional requirements for a topographic display to be used as a ground-based mission-planning work station and a topographic display to be used as an aircraft-mounted navigation and tactical decision-making aid.

- Identify computer-graphic techniques and equipment characteristics for the mission-planning and aircraft-mounted displays that best fulfill the functional requirements.

- Develop conceptual designs for the mission-planning and aircraft-mounted displays that meet Army aviation task performance requirements and human factors engineering criteria.

PROJECT APPROACH

The approach employed to meet the project objectives consisted of iterative cycles of system conceptual design efforts supplemented by a series of information-gathering activities. The information-gathering activities outlined below were critical in the identification of functional requirements as well as in the evaluation of the emerging design features.

LITERATURE REVIEW

Current documents related to Army aviation tasks were reviewed to identify functional requirements for the topographic display. Examples of such documents include Gainer and Sullivan (1974), Garlichs, Cox, Hockenberger, and Smith (1979), Rogers and Cross (1979), FM 1-1 (1976), FM 21-26 (1969), FM 17-50 (1977), FM 90-1 (1976), FM 17-47 (1977), FM 100-5 (1977), and FM 101-5-1 (1980). In addition, recent publications pertaining to computer graphics (e.g., Newman & Sproull, 1979) and man-computer interactions (e.g., Engel and Granda, 1975; Smith, 1981) were reviewed and principles applicable to CGTD systems were extracted.

OBSERVATIONS

Aviators were observed during the conduct of mission-planning activities performed to meet the requirements of hypothetical missions selected by the author. Aviators of a broad range of ranks and responsibilities (see Acknowledgments) were requested to participate in these exercises in order to study the flow of mission-planning information, and determine its development and refinement at various echelons. Aviators were also observed performing navigation tasks during NOE flight in a variety of terrain types.

INTERVIEWS

Interviews with cognizant aviators and engineers were conducted throughout the course of the project. Formal interviews were scheduled with aviators of the 101st Division to aid in determining the optimal aviator-computer interactions for the processing, storage, and display of topographic and tactical data. Subsequent formal interviews took place with aviators of the 2nd Armored Division and the 6th Cavalry Brigade in order to evaluate specific characteristics of the preliminary conceptual designs. During these interviews, mission scenarios and simulated control and display surfaces were employed to graphically portray the capabilities of the system and encourage comments and suggestions from the aviators.

Periodic informal interviews were held on site and by telephone with experienced aviators serving as instructors at the Career Training Division of the U. S. Army Aviation Center. Other informal interviews took place with hardware and software experts familiar with the state-of-the-art in applicable computer technology, especially AVRADA personnel. These informal interviews served to provide information necessary to make design trade-off decisions in a timely manner.

SURVEY

Aviators of the 101st Division completed a questionnaire designed to identify current practices with paper maps that might influence the design of a CGTD, to examine opinions of aviators regarding the basic requirements for such a system, and to determine aviators' assessments of various special features of a CGTD. The results of this survey are presented in Appendix A of this report.

HUMAN ENGINEERING ANALYSES

The functional requirements identified during the course of the project were analyzed to determine general display and control requirements as well as specific information communication requirements. Alternative design concepts were developed to satisfy these requirements, and were evaluated on the basis of their incorporation of established human factors engineering principles and criteria. These analyses are discussed in greater depth in Section III of this report.

ORGANIZATION OF THE REPORT

Succeeding sections of this report present two different types of information. For readers not thoroughly familiar with these topics, Section II provides a background in the missions, organization, and procedures of Army aviation units. This section is unique because it combines established doctrine, rapidly evolving tactics, realistic unit procedures, and multiple viewpoints (from different aviator duty positions) to describe the operations of aviation-intensive units as they relate to the requirements for topographic display systems.

Section III of this report presents a discussion of the general philosophy and the human engineering criteria that guided the design of the recommended system. In addition, the aviators' requirements and the present deficiencies in meeting these requirements are summarized, and the components and functions of the system are described. In order to clarify the operation of the system, the multifunction control-display units designed for the ground-based and airborne systems are discussed at length.

SECTION II

MISSIONS, ORGANIZATION, AND MISSION-PLANNING PROCEDURES OF SELECTED ARMY AVIATION UNITS

OVERVIEW

This section of the report describes the missions of selected Army aviation units, the organization of these units, and the general procedures employed in planning missions in a high-threat environment. The purpose of this section is to provide an overview of Army aviation considerations related to the development of a computer-generated topographic display system--in particular, the mission-planning considerations. The study supporting this section attempted to identify the following factors for each of several types of aviation units:

- Origin of mission orders
- Elaboration of orders through echelons
- Sources of battle-area intelligence
- Distribution of mission and intelligence information
- Responsibilities for flight route selection
- Time available for mission-planning activities
- Special communication and coordination requirements
- In-flight standard operating procedures

It was not within the scope of the study to identify all of these factors for all types of missions for all types of aviation units. Rather, it was intended that representative samples of units, missions, and organizational structures be included from an "aviation-intensive" Army division in order to provide a useful description of the factors typically involved in mission planning. Sixteen aviators from the 101st Airborne Division participated in the study. These aviators averaged over 2000 hours of helicopter flight, and over 500 hours of nap-of-the-earth flight. They were members of assault helicopter units, attack helicopter units, and air cavalry units, and collectively had experience in eleven types of helicopter aircraft. The study was conducted as a series of intensive interviews supplemented by written survey instruments and map-annotation exercises spanning one week in December 1980.

The results of the study confirmed that Army aviation units employed as members of the combined arms team perform an impressive range of diverse missions. Although many of these units are equipped with identical aircraft and similar auxiliary equipment, they are integrated throughout the entire force structure of the Army and their roles and missions depend upon the arm that the aviation unit serves and on the specific tactical situation.

The continuously improving helicopter technology has spurred doctrinal planners to task Army aviation with ever more critical and complex tactical requirements. As a result, the mission-planning burden on the individual aviator has increased greatly in recent years, especially since air superiority can no longer be assumed, and terrain flight is necessary for survival. To make matters more difficult for the aviators, the emerging doctrine leans heavily upon the helicopters' ability to provide a rapid response over a wide frontage. The wide frontage limits the aviators' ability to develop a familiarity with the "lay of the land," and the rapid-response tactical requirement often limits the time available for careful mission planning. In short, as the aviators' mission-planning responsibilities have grown, the time available for their performance has diminished.

The result of this inconsistency is that "short-cuts" are taken in the mission-planning process. Intelligence available at the supported unit headquarters, or even at the aviation unit Tactical Operations Center (TOC), may not reach the aviators for whom it would be most useful because there is insufficient time for thorough briefings, map annotations, or overlay preparation. Instead, the aviators may be provided only with a few grid coordinates related to the mission.

Other critical "short-cuts" are taken with regard to landform contour study. The understanding of available cover and concealment is absolutely essential to survival in the high-threat environment. Unfortunately, even with generous amounts of planning time, contour-map interpretation is an extremely demanding task. When planning time is limited, however, aviators tend to resort to simple "rules of thumb"--such as staying behind major land masses, avoiding large open areas, flying along streams, and staying outside the maximum range of known enemy radar installations.

As described in this section, the range of helicopter missions has become quite broad, this diversity being partly a function of improved technology. The technological thrust in Army aviation, however, has primarily been concentrated on improved aircraft performance and enhanced weaponry, and has sometimes actually increased the aviator's information-processing workload.

In the coming years, it will be essential to focus attention on assisting the aviation unit commanders and the individual aviators with the performance of their mission-planning and in-flight decision-making requirements so that much greater amounts of information may be processed, and so that this processing may be done much more rapidly than ever before. Computer-generated topographic display systems for mission planning and in-flight use have the potential of fulfilling these crucial goals.

THE AIR ASSAULT DIVISION

MISSION AND ORGANIZATION

The mission of the air assault division is to destroy enemy forces; to perform the full range of offensive and defensive operations while capitalizing on its inherent mobility and unique air assault tactics; and to provide a highly mobile reconnaissance, security, or reserve force for larger units. The special capabilities of the air assault division are achieved primarily through the crucial role of helicopter mobility:

- Operations over a wide frontage in all types of terrain
- Immediate response and rapid maneuvers to weigh the battlefield at the critical time and place
- Economy of force roles, screening, raids, and exploitation
- Destruction of enemy armored and mechanized forces
- Area interdiction operations behind the enemy forward defense area
- Surveillance, target acquisition, and reconnaissance operations over wide areas

Figure 1 shows the organizational structure for a type of air assault division. Although all elements of the division use helicopters to some extent, the majority of the division's aircraft are organic to the aviation group and the air cavalry squadron.

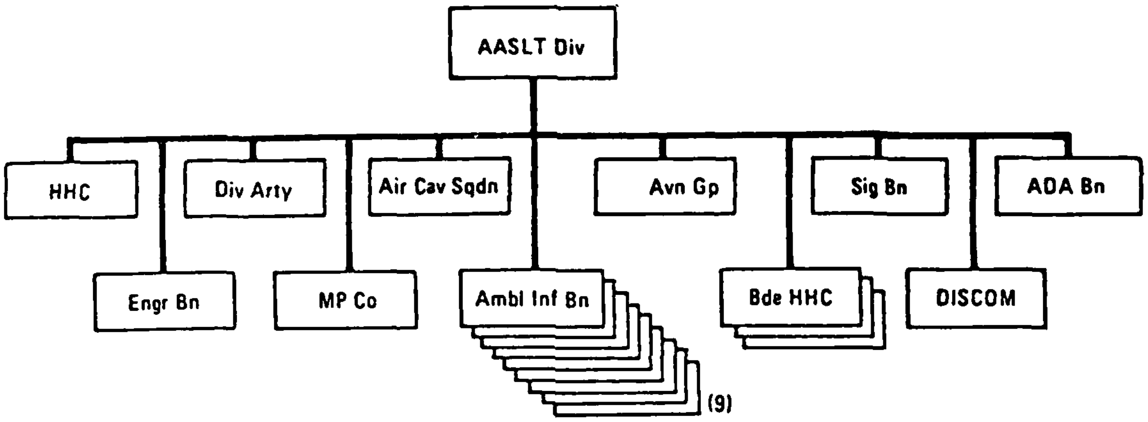

Figure 1. A type of air assault division.

THE AVIATION GROUP

MISSION AND ORGANIZATION

The mission of the aviation group is to provide aviation support to the air assault division and to provide aviation special staff personnel to division HQ. Figure 2 shows the organization of the aviation group. The aircraft in the aviation group are concentrated in the two assault helicopter battalions, the assault support helicopter battalion, and the attack helicopter battalion.

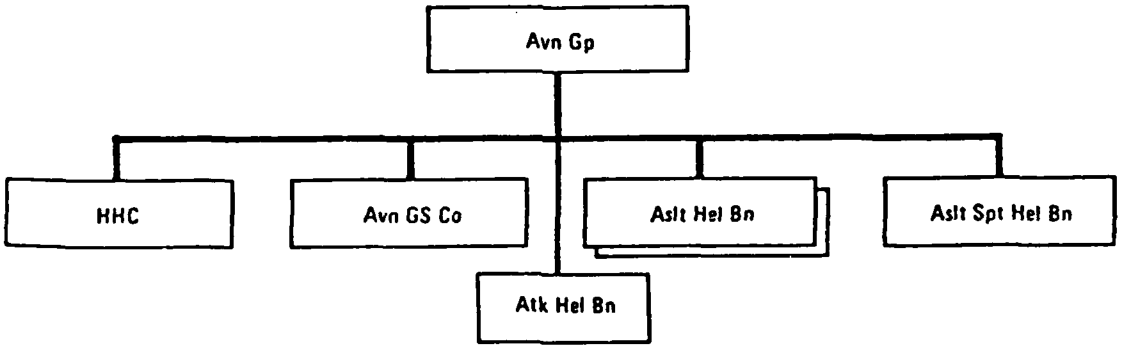

Figure 2. The aviation group.

THE ASSAULT HELICOPTER BATTALION

MISSION AND ORGANIZATION

The mission of assault helicopter units is to provide tactical mobility for combat troops, weapons, equipment and supplies, and to conduct air assault operations throughout the battle area. Typical tasks of assault helicopter units include delivery of ground combat power, transport of engineers, blocking enemy movement, raids, reinforcement of forward forces, emplacement of aerial mines or unattended ground sensors, and resupply. The organizational structures of the assault helicopter battalion and its subordinate assault helicopter companies are shown in Figure 3 and Figure 4. These figures also indicate the numbers and types of aircraft typically found in these units. Notice that assault helicopter units include attack aircraft as well as assault helicopters.

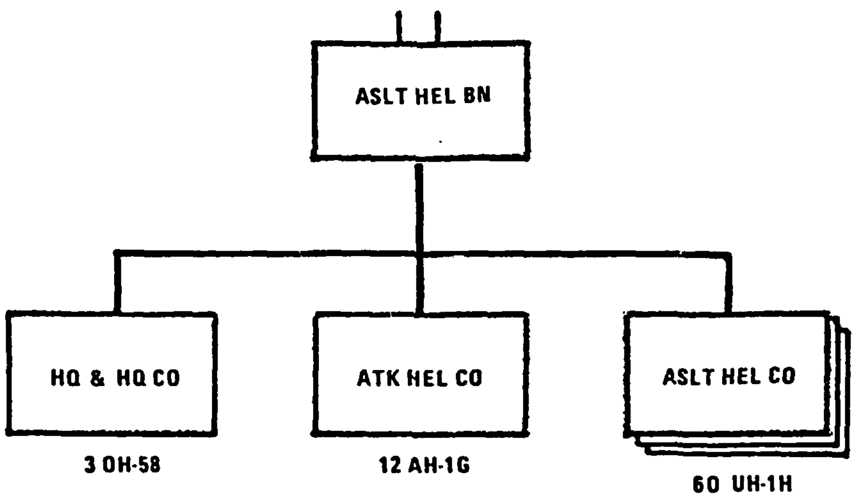

Figure 3. The assault helicopter battalion.

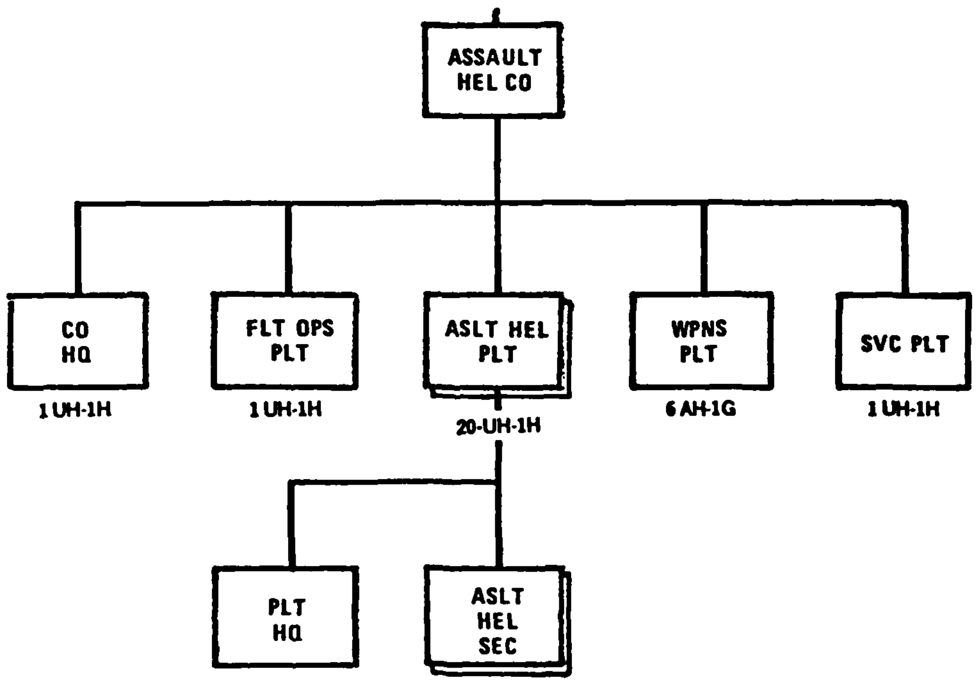

Figure 4. The assault helicopter company.

MISSION PLANNING IN ASSAULT HELICOPTER UNITS

Orders for an air assault mission originate from the commander of the supported infantry unit (usually a brigade or battalion). The infantry unit commander and his S-3, in coordination with aviation liaison officers, define the locations of pickup zones (PZ's) and landing zones (LZ's), and are usually not involved with flight route selection. The aviation unit commander, or his liaison officer, the combat aviation party (CAP), may assist the infantry commander in planning in order to achieve maximum cover, concealment, and surprise. The CAP communicates by radio with the TOC at aviation battalion or company headquarters. In turn, the assault helicopter company commanders or platoon leaders are notified regarding mission requirements. The aviation unit commanders may communicate by radio with the CAP for additional information, or, if time permits, arrange for a face-to-face meeting and situation briefing. Time for such meetings is expected to be available in less than 10 percent of the cases.

Route selection may be performed at any one of several levels. In some cases, the brigade airspace management element (BAME) may effectively determine routes due to their control of air corridors open to helicopter flight. Corridors may be closed due to Air Force, friendly artillery, and air defense artillery (ADA) missions. Routes are sometimes planned by the company commander or the company TOC. In most cases, however, the air assault platoon leader is responsible for selecting primary and alternate routes and return routes. It is unusual for aviators subordinate to the platoon leader to assume any role in route selection.

The time available for mission planning varies greatly with the circumstances. For logistical flights, as much as 12 hours may be available. For large troop movements, such as the transport of an entire infantry battalion, six hours of planning time would probably be available. In all other situations, planning time would be a maximum of two hours and an average of 15 to 20 minutes. It is not at all unusual for effectively no time at all to be available for planning. For example, an infantry unit may come under surprise attack by a numerically superior enemy force and request immediate extraction.

The amount of information furnished to the aviators is proportional to the planning time available. In the above example of an emergency extraction the aviators are unlikely to have any more information than the coordinates of the PZ and a very general description of enemy activity. At the other end of the spectrum are the cases in which aviation unit commanders can visit the CAP, study the situation map, receive map overlays and carefully annotate their maps with mission-relevant information. In most cases there will not be time to produce overlays for every aviator and often not even the platoon leader will receive an overlay. Map study and annotation may be minimal. Critical flight data is instead conveyed to flight leaders by an air movement table (AMT) that lists the coordinates of PZ's, air control points (ACP's), release points (RP's), and LZ's; it also lists the required arrival times at each of these sites. When possible, the aviators will receive a complete briefing on the route of flight. If only a very cursory briefing is possible, the aviators may simply follow the flight leader rather than marking the flight route on their maps.

In addition to the information on the AMT, the flight leader will sometimes have information regarding preplanned artillery targets, supplementary LZ's, and supplementary PZ's selected by the infantry units. These sites are identified by map annotations or coordinates and are designated by words or alphanumeric codes. Enroute these codes may be used to communicate with infantry or artillery units, rather than employing grid coordinates which would identify friendly positions. Examples of map annotations used by a flight leader are shown in Figure 5.

ENROUTE PROCEDURES IN ASSAULT HELICOPTER UNITS

In typical troop insertion missions, assault helicopters will be grouped in flights of three to five aircraft. When possible, different flights will use different routes. Often, however, up to three flights of five aircraft will use the same route, each group separated by 700 to 800 meters. The AMT stipulates times for arrival at PZ's, ACP's, RP's, and LZ's for each flight. Every effort is made to adhere to this schedule, both for reasons of overall mission coordination and for the most effective use of artillery support in suppressing enemy activity along the flight route. If a flight falls behind schedule by as much as two minutes, the flight leader must notify the TOC so that appropriate measures may be taken. To aid in the proper timing of the mission, the most easily detectable and identifiable topographic features are selected for use as ACP's. Certain positions along the route prior to and subsequent to the LZ may be employed for "false insertions" to deceive the enemy. At these positions the aircraft will hover just off the ground for long enough to simulate a troop insertion before resuming movement along the route.

Upon arrival at the RP, a radio message is transmitted to stop artillery fire on the LZ, usually 3 to 5 kilometers away. The aircraft move into a column formation for their final approach to the LZ, attempting to time their arrival "to the second" in accord with the AMT. When the infantry troops have been inserted, the aircraft may, depending upon the mission, return to the friendly area, or land nearby in laager[1] areas to await the extraction of the troops.

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[1] Laager: (obsolete Afrikaans, from German) camp, especially an encampment protected by a circle of wagons. The word is used by Army aviators to mean a holding position safe from detection, whether in friendly or enemy areas.

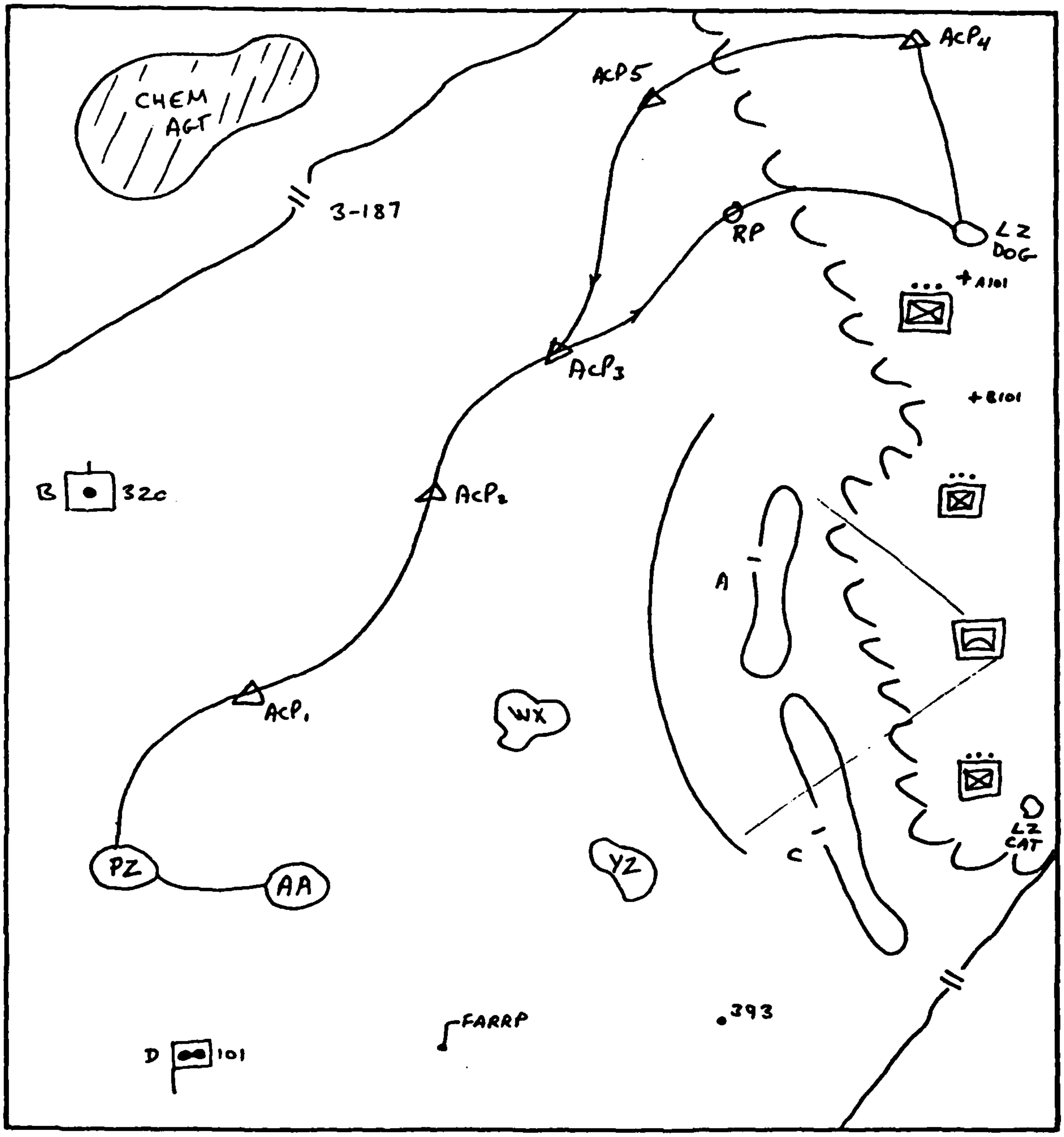

Figure 5. Examples of map annotations likely to be employed by the flight leader during an insertion mission conducted by an assault helicopter unit.

No map annotation is performed in flight unless hostile fire is taken from a position not previously identified with enemy activity. Communications regarding mission progress employ word, letter, or number codes to identify preplanned geographic positions; additional sites may be identified by range and bearing from these preplanned positions. Grid coordinates are transmitted only to identify enemy positions. In some situations, such as "delay in sector" operations, a large number of potentially useful sites will be code named well in advance of their employment so that rapidly changing situations may be transmitted by radio to the aviators.

THE ASSAULT SUPPORT HELICOPTER BATTALION

MISSION AND ORGANIZATION

The mission of the assault support helicopter battalion is to provide air transport of personnel and supplies for combat support and combat service support operations, and to provide rapid battlefield displacement of fire support elements. Typical tasks of assault support helicopter units include movement of bulk supplies, artillery pieces, vehicles, air defense weapons, anti-tank weapons, ammunition, and combat personnel. The organizational structures of the assault support helicopter battalion and its subordinate assault support helicopter companies are shown in Figures 6 and 7.

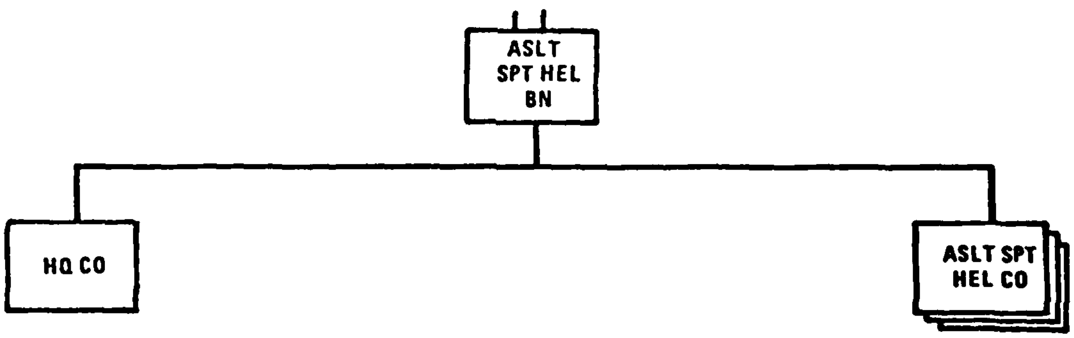

Figure 6. The assault support helicopter battalion.

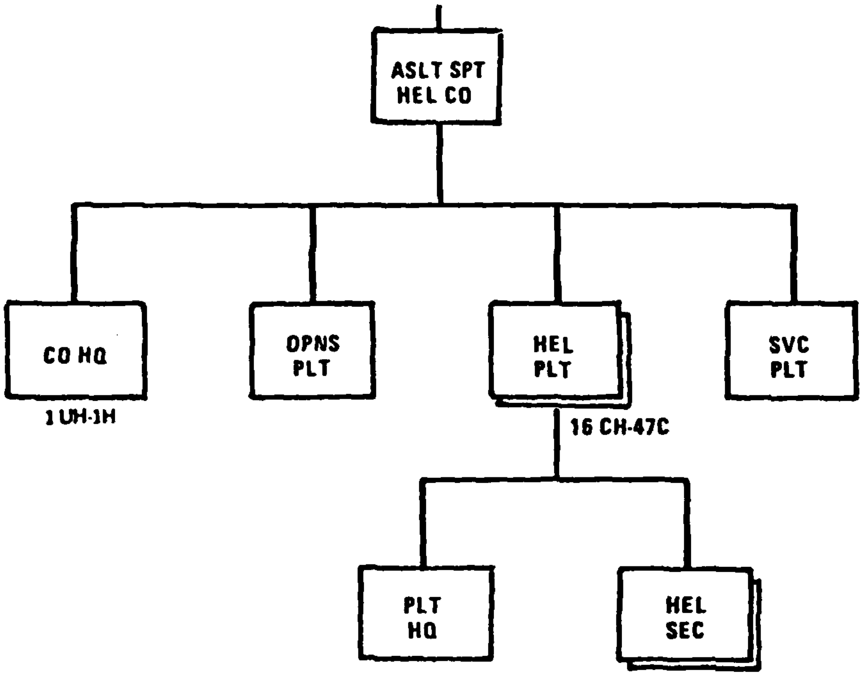

Figure 7. The assault support helicopter company.

MISSION PLANNING IN ASSAULT SUPPORT HELICOPTER UNITS

Assault support helicopter companies are usually provided to the infantry brigades. An entire assault support helicopter battalion may be employed in the airlift of a large combined arms task force. The difficulty of mission planning varies with the role of the assault support units. Much of the logistical flying is done in relatively secure areas, covering long distances well above terrain-flight altitudes and, for this reason, the planning and navigational tasks of the medium-lift helicopter aviators are often minimized. Nevertheless, the necessity for forward displacement of ammunition and fuel, or reinforcement of infantry units under heavy enemy pressure sometimes requires that more extensive mission-planning efforts be conducted. In high-threat environments of the future, the assault support helicopter will be expected to perform contour flight and mission planning requirements may begin to approximate those currently addressed by assault helicopter units.

THE ATTACK HELICOPTER BATTALION

MISSION AND ORGANIZATION

The mission of the attack helicopter battalion is to destroy or disrupt enemy armor and mechanized forces by aerial firepower. Typical tasks of attack helicopter units include combined arms operations, raids on enemy flanks and rear areas, special anti-armor operations, reinforcement, and exploitation. The organizational structures of the attack helicopter battalion and its subordinate attack helicopter companies are shown in Figures 8 and 9.

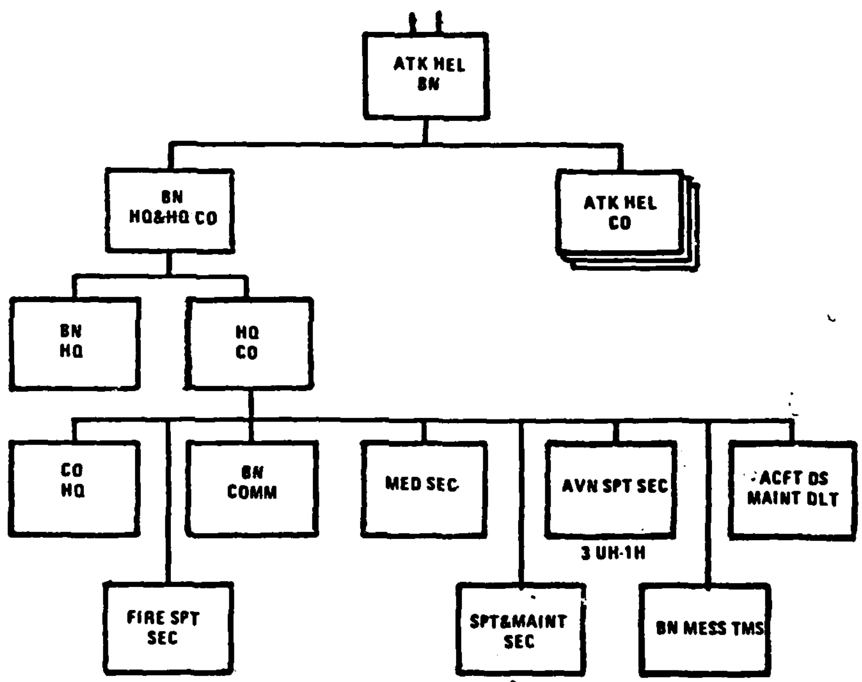

Figure 8. The attack helicopter battalion.

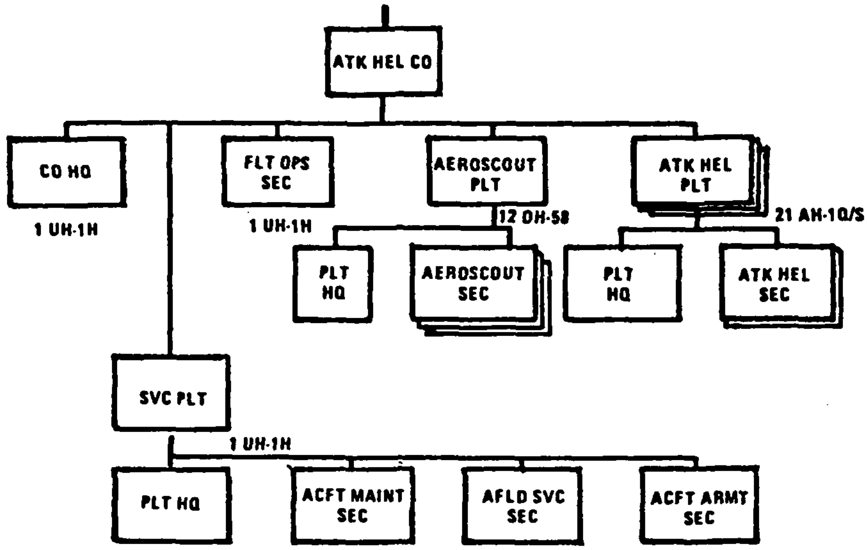

Figure 9. The attack helicopter company.

MISSION PLANNING IN ATTACK HELICOPTER UNITS

Orders for attack helicopter missions will typically originate at the infantry brigade supported by the attack helicopter company. The attack helicopter company commander will design his overall battle plans to complement the brigade scheme of maneuver. The company commander will usually examine the brigade situation map to determine the friendly and enemy disposition and other tactical information to be conveyed to his pilots. Normally, the company commander's plan indicates specific objectives. In particularly fluid situations, the plan contains only general guidelines—recognizing that the plan is only a starting point and that changes will occur as dictated by the tactical situation. The company commander gives the platoon leaders more or less guidance depending upon their experience. In some cases, the company commander might plan tentative firing positions and holding areas, but would seldom select the flight routes. Once on site, platoon leaders may "brief back" to the company commander regarding necessary changes in these positions.

Battle teams may be composed of any mixture of attack and scout aircraft, but a typical team is composed of three scouts and five attack aircraft. In addition

to the pilot, one of the scout aircraft normally carries the battle team commander (usually, but not necessarily, the platoon leader). A second scout aircraft may carry an artillery liaison forward observer. The third scout may carry a forward air controller for Air Force liaison.

The battle team commanders are briefed at least once every day at the company TOC. In some cases, sufficient time is available to produce and distribute overlays. Otherwise, as much of the briefing information as possible is recorded on the battle team commander's map. Potentially important terrain sites, such as fall-back positions, may be selected and code-named for later use in fragmentary orders (fragos).

Before briefing his pilots, the battle team commander spends considerable time in map study and planning. Examples of the battle team commander's map annotations are shown in Figure 10. In addition to study of the tactical situation in general, very careful attention is given to the masking provided by terrain contour. An assessment of masking is critical due to its impact on selection of concealed flight routes and advantageous kill zones. Masked flight routes are, of course, selected to degrade the enemy's ability to visually, optically, or electronically detect or locate the aircraft, and are the concern of all army aviators. Kill zones are the particular interest of attack helicopter units, and their selection involves the following considerations:

- Limited trafficability for tanks, so that escape routes are few and can be guarded
- Firing positions allowing engagement at maximum standoff range
- Sufficient firing positions to allow 300 meter spacing between aircraft
- The likely availability of flank shots at enemy armor
- Firing positions with cover and concealment from the front and a terrain backdrop to the rear (to prevent silhouetting of the aircraft when it unmasks)
- Alternate firing positions for use after enemy detection of the primary positions

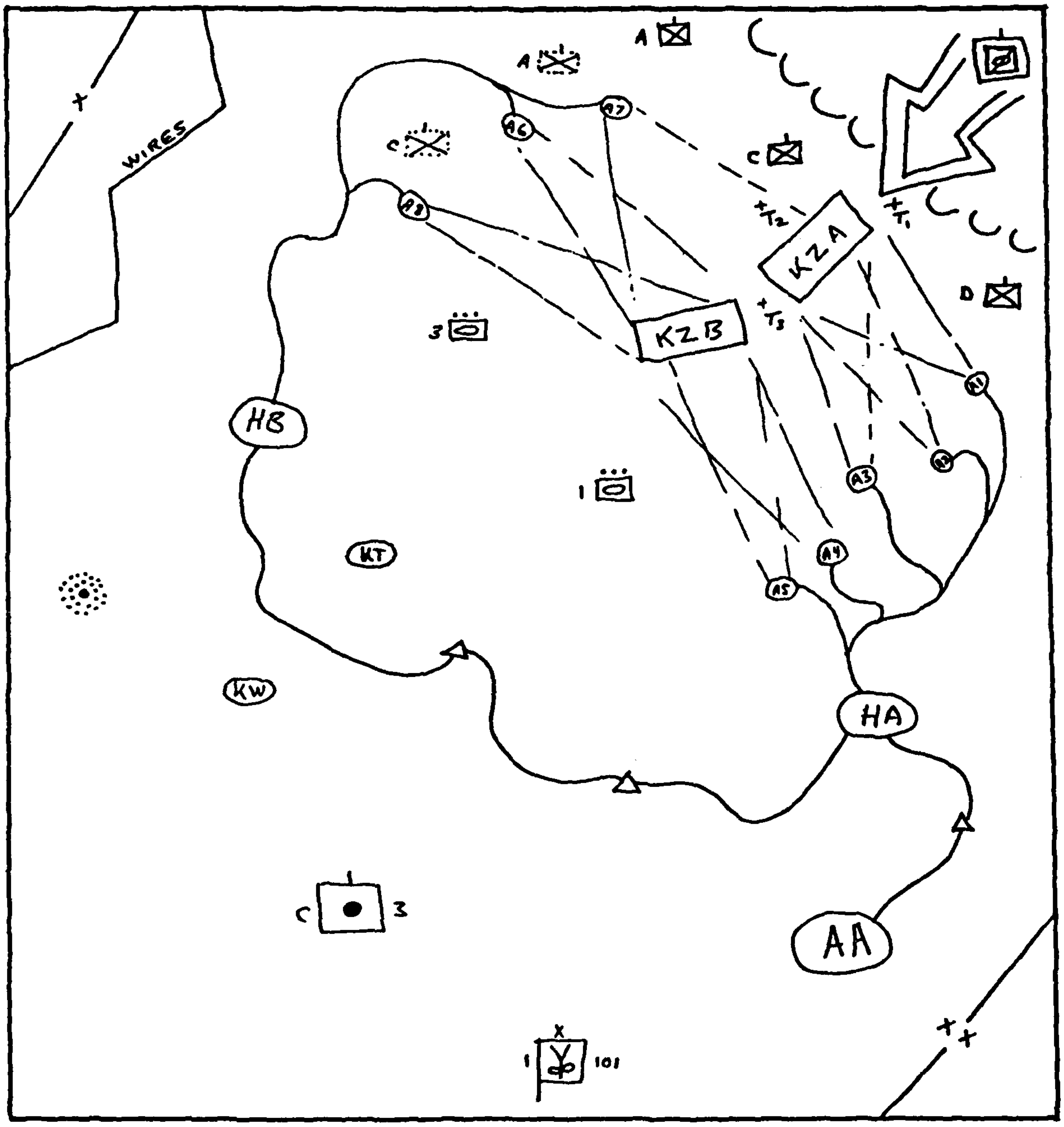

Figure 10. Examples of map annotations likely to be employed by the battle team commander of an attack helicopter battalion during a reinforcement mission.

The ability to consider all of these factors requires both skill in map interpretation and sufficient time to apply this skill. In situations in which sufficient time or sufficient intelligence regarding the enemy's movements is not available, the planning must be done in the battle area, as described in the following section.

BATTLE AREA PROCEDURES IN ATTACK HELICOPTER UNITS

In the battle area, teams of scout and attack aircraft work together with great flexibility. Although the conduct of missions varies greatly, the cycle of events listed below is useful in exemplifying team procedures.

- The scouts search for and locate targets
- The scouts identify appropriate firing positions (based on the considerations outlined in the previous section)
- One scout returns to the holding area to meet the attack aircraft, while other scouts continue to observe the enemy
- The scout informs the attack helicopter aviators of the nature and location of the targets and if dismounted, shows the attack pilots the selected firing positions and route to these positions
- The scout may, instead, simply lead the attack aircraft to the firing positions
- At the appropriate moment, the scout gives the handoff—for example: "From your attack position, at 270 degrees, at 2500 meters, expect T-62 tank near tall tree."

Communication between aircraft in the battle team is essential but awkward. Because it is desirable to minimize radio traffic, communication by hand signals has been attempted. This effort has met with some success, although the signals are not standardized and must be briefed before the mission. Another communication technique under evaluation is the "SAMS" or "Send-A-Message System," consisting of color-coded, numbered cards that can be held up near the canopy and seen between aircraft. Neither of these methods effectively conveys geographic information, such as target or firing position locations.

THE AIR CAVALRY SQUADRON

MISSION AND ORGANIZATION

The mission of the air cavalry is to perform reconnaissance, security, and surveillance activities. The air cavalry units provide real-time intelligence concerning the enemy, terrain, and weather throughout the battle area and alert against or provide protection against enemy observation and attack. Typical tasks of the air cavalry squadron include: intelligence gathering operations, guard operations (advanced, rear, or flank), limited objective attacks, and screening operations. The organizational structures of the air cavalry squadron and its subordinate troops are shown in Figures 11 and 12.

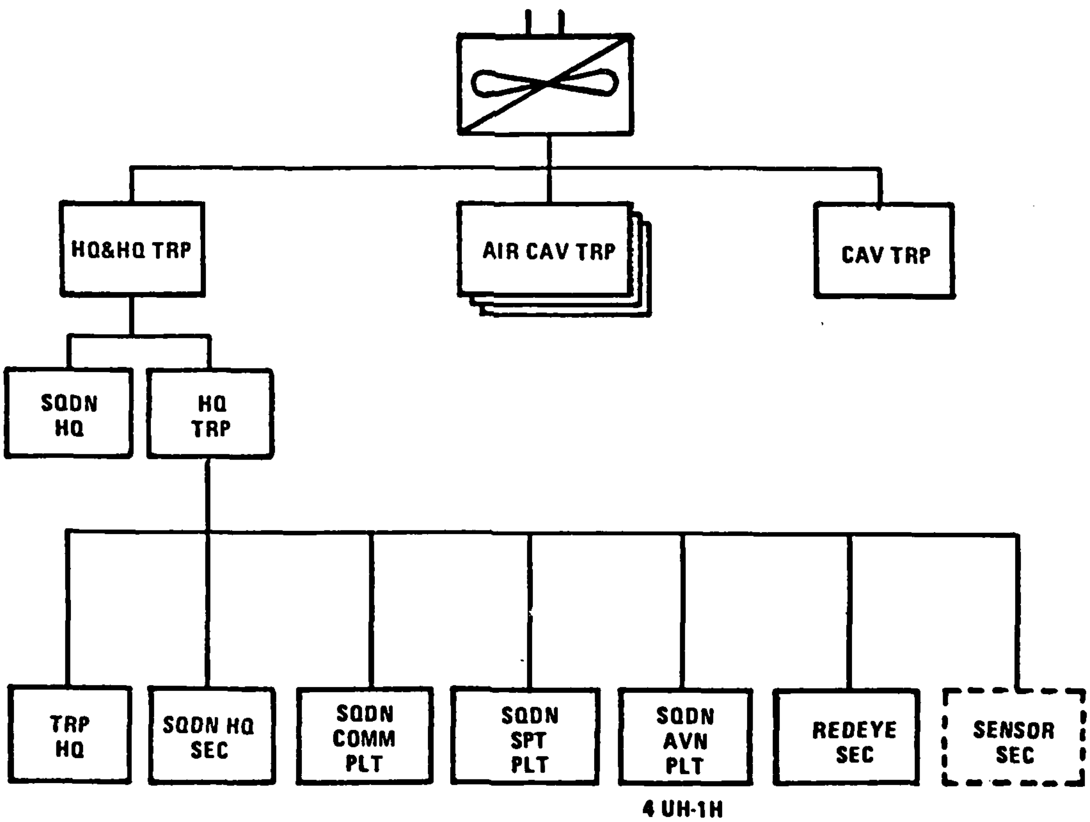

Figure 11. The air cavalry squadron.

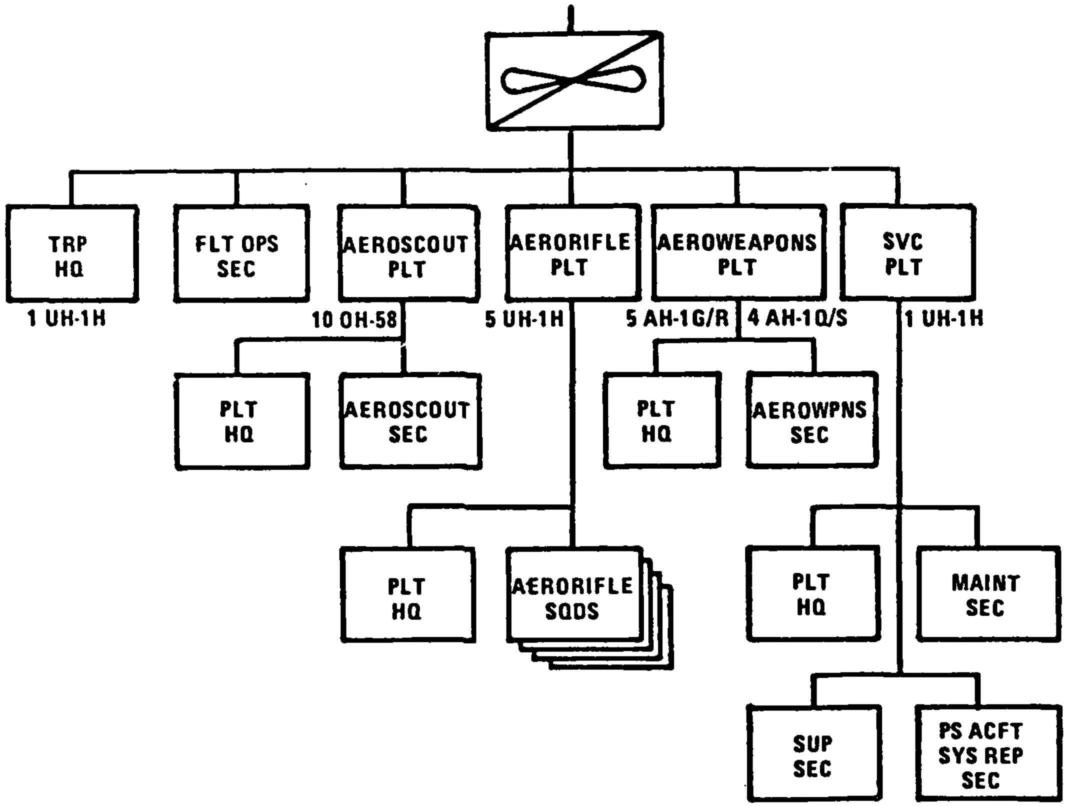

Figure 12. The air cavalry troop.

MISSION PLANNING IN THE AIR CAVALRY SQUADRON

There is little doubt that the air cavalry performs a greater variety of missions than any other type of aviation unit. The result of this variety of missions is that the air cavalry unit commanders must be able to quickly organize his resources to best accomplish a given mission. Scout aircraft, attack aircraft, and utility aircraft carrying infantrymen may be organized in any mixture. This flexibility demands very decentralized decision-making and requires that junior leaders make rapid decisions of far-reaching consequences.

It would be unusual to find the air cavalry squadron operating as a unit. Typically, the air cavalry troops are attached to brigades, and in some cases, are placed under the operational control of a single maneuver battalion. The supported unit participates very little in the planning of air cavalry activities. For example,

a brigade commander might order the air cavalry troop commander to provide a screen on the brigade flank. Other than the brigade situation overlay, the air cavalry troop commander would receive no further information and would be given a free hand in the planning and conduct of the mission. Overall mission plans are generated at the troop TOC through the joint efforts of the troop commander, the operations officer, and the platoon leaders. Platoon leaders usually select flight routes, although they may delegate this responsibility to an experienced senior warrant officer. In the aerorifle platoon, squad leaders may participate in the selection of LZ's and PZ's. After initiation of the mission, decision making is a continuous in-flight activity, involving the selection of new routes, LZ's, firing positions, and so forth.

Because the primary mission of the air cavalry is reconnaissance, they are more likely than other aviation units to fly in areas where the tactical situation is unknown or unclear. Thus, although air cavalry unit leaders attempt a thorough map study before flight, they may be given little information regarding the enemy situation and must concentrate on terrain analysis and the potential for enemy movements.

It follows that pre-flight map annotation is minimal for air cavalry activities. The FEBA, brigade boundaries, battalion boundaries, hazards, check-points, rally points, FARRP's, and some other items of information are noted on the map. Map clutter is of such concern that the brigade overlay is never used and pilots may attempt to memorize their routes rather than mark them on the map. Instead of annotating the map, as much information as possible is kept on knee-boards. Coordinates of key positions are listed so that their positions may be located on the map when and if they are required. If the map must be extensively marked, a second, unmarked map will also be carried. Examples of map annotations made prior to a route reconnaissance are shown in Figure 13. Flight route study and selection is a never-ending activity for air cavalry aviators because their mission seldom requires that they select a "best" route, but instead seek out enemy activity on all potential routes and areas. This requirement, along with the requirement to avoid an enemy ambush, dictates that flight routes be changed frequently.

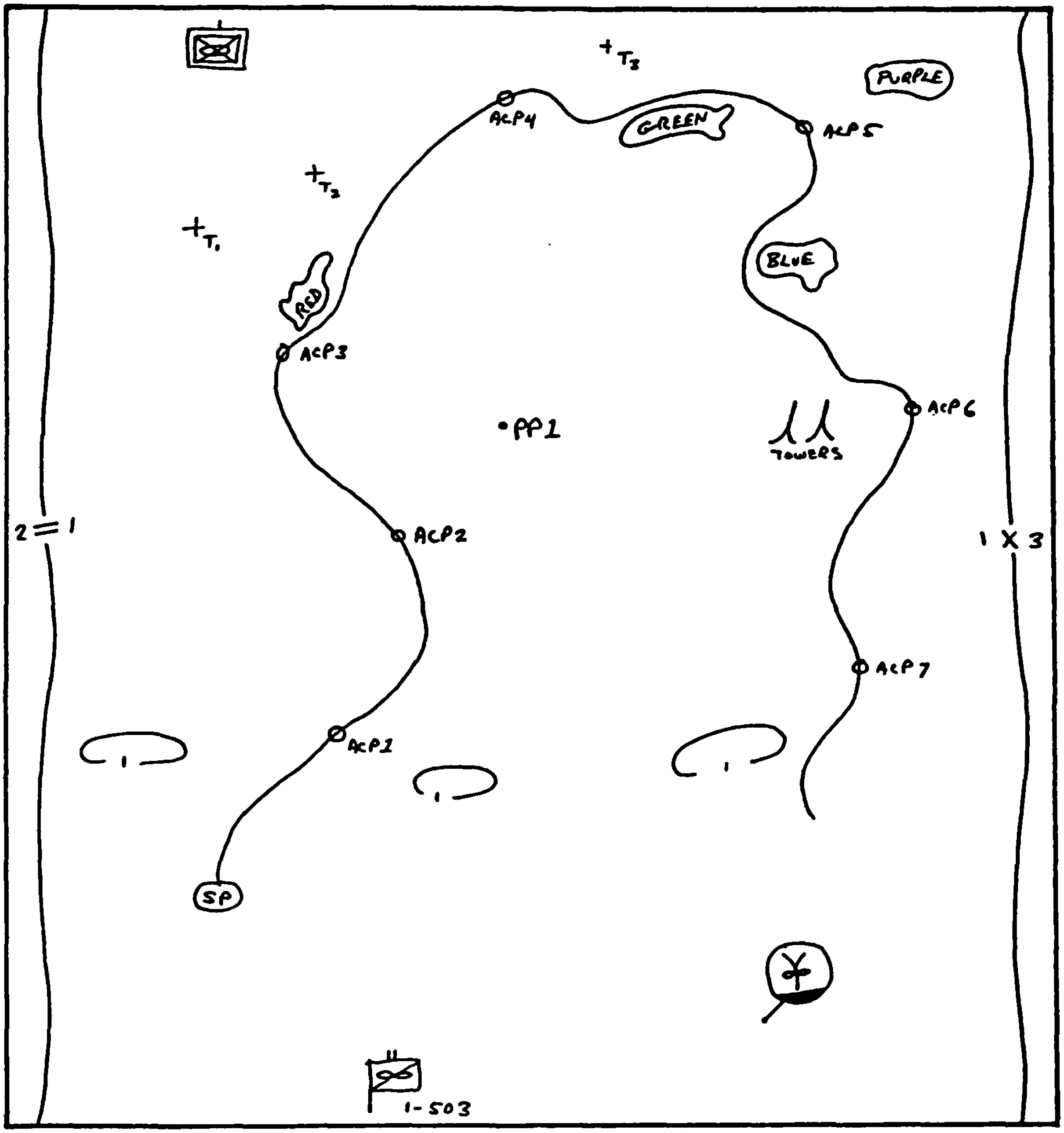

Figure 13. Examples of map annotations likely to be made by an aeroscout platoon leader prior to the conduct of a route reconnaissance by an air cavalry unit (additional annotations would be made during flight).

The time available for mission planning varies from about 30 to 40 minutes for a normal, planned mission to 15 minutes or less for a "rapid reaction" mission. When missions are cyclic, the aviator has about 45 minutes between flights. This time is divided into three 15-minute segments: one for care of the aircraft, one for mission planning, and one for relaxation. Rapid reaction missions are initiated by "warning order" (less information than a fragmentary order). These missions may provide such a short advance notice that detailed route selection is nearly impossible.

As mentioned above, air cavalry teams may be organized in many different ways. This flexibility makes it difficult to select a "typical operation". Nevertheless, the general responsibilities of each platoon remain substantially constant, and these are described in the following three sections.

AEROSCOUT PLATOON PROCEDURES

The key aircraft in all air cavalry missions are aeroscouts. The mission commanders nearly always ride in scout aircraft, and the scouts are responsible for the gathering and communication of intelligence. It is also up to the scouts to decide whether and when to involve others (such as friendly artillery, tactical air support, an attack helicopter unit, or air cavalry attack aircraft) in a combat situation. It is also the responsibility of the scouts to perform in-flight map annotation and logging of enemy activity, to make spot reports by radio to the operations centers, and to provide a written situation report for the troop TOC. As air cavalry teams are alternated between the FEBA and the FARRP, they attempt to meet at a rally point so that the scout most recently at the FEBA can provide current information to the scout on the way to the combat area.

In addition to the performance of area, zone, and route reconnaissance, and in addition to the communication duties outlined above, it is clearly necessary for the aeroscout pilot to navigate with great accuracy. The aeroscout pilot, however, has less time and less human or hardware assistance for navigation than do the pilots of other types of aircraft. Unlike utility and attack aircraft, only one pilot is normally allocated to the scout aircraft and unlike the attack aircraft or the Blackhawk aircraft, the scout does not have doppler navigation equipment. A crew

chief usually accompanies the aeroscout pilot, but he is seldom able to perform navigation tasks beyond indicating the current position on the map with his finger, as directed by the pilot. This service is so minimal that most aeroscout pilots would prefer that the crew chief instead man an M-60 machine gun for small arms fire suppression. The addition of a second pilot is always preferable, but not usually possible. The situation is particularly difficult when the scouts are returning from missions and receive orders by radio to perform reconnaissance in additional areas. In these cases, the aeroscout pilot may simply land the aircraft and study the map while an attack aircraft hovers nearby in an overwatch role.

AEROWEAPONS PLATOON PROCEDURES

The attack aircraft pilots in an air cavalry unit perform less map study, mission planning, and map annotation than do pilots flying the same aircraft in the attack helicopter battalion. This dissimilarity is due to the different mission requirements in the air cavalry. In the air cavalry the scouts are primarily responsible for the map-related planning activities, and the primary role of the attack aircraft is to protect the scouts. Firing upon targets of opportunity (such as tanks, armored vehicles, aircraft on the ground, and troops in the open) is a secondary mission for attack aircraft in air cavalry units. Normally, the attack aircraft remain about 1000 meters to the rear of the scout aircraft but attempt to keep the scout in sight. In some circumstances the scout will request the attack aircraft to wait in a holding area while the scout reconnoiters forward positions. The two aircraft maintain continuous radio communication, and the attack aircraft may assist in passing spot reports, in providing information about current geographic position, and in handing off targets to gunships from an attack helicopter battalion. Mission-planning requirements for air cavalry attack aircraft become more demanding when the troop is called upon to conduct raids on the enemy rear or to conduct limited-objective attacks on lightly defended areas. Such tasks are secondary and are less frequently performed than the reconnaissance, surveillance, and security tasks that place the planning burden primarily on the aeroscout aviators.

AERORIFLE PLATOON PROCEDURES

The aerorifle platoon provides a small infantry unit for use by the air cavalry troop in those cases demanding the capabilities of ground forces. The most usual requirement for aerorifle units is that of gathering information not ascertainable from aircraft, such as: a) reconnaissance of heavily vegetated areas, buildings, or other potential enemy positions, and b) classification of bridges in terms of their load-bearing capacity, width, overhead clearance, and so forth. Another typical task is the conduct of hit-and-run ambushes in enemy territory--assisted by friendly artillery to cover the rapid disengagement and return to friendly areas. The entire aerorifle platoon may be involved when rapid reaction forces are required to disrupt enemy activities. It is more typical, however, to employ individual aerorifle squads for ambushes or reconnaissance patrols. For missions that require only a squad, mission planning and conduct requires the coordinated efforts of the utility aircraft pilot and the squad leader. As in assault helicopter units, the infantry leader participates in the selection of LZ's and PZ's and the aviator selects the route of flight.

The conduct of aerorifle missions is somewhat similar to assault helicopter operations, but on a smaller scale. If the movement requires more than one utility aircraft, the aircraft fly in formation--separated by no more than 10 rotor discs. The ground troops are inserted at the LZ and their aircraft move back to a holding area until the appropriate time for flight to the PZ. Alternate PZ's are specified in case enemy activity or weather problems interfere with use of the primary PZ's. Correct arrival time of the aircraft at the PZ is critical when enemy contact is anticipated. Aerorifle missions may also be conducted in a series of brief insertions coordinated with the reconnaissance activities of the aeroscout and aeroweapons teams, which precede the aerorifle aircraft. Aeroscouts select positions that should be investigated by ground troops, and the utility aircraft are provided overwatch protection by the attack aircraft.

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SECTION III

DESCRIPTION OF THE RECOMMENDED SYSTEM

This section of the report describes the configuration and operation of the recommended computer-generated topographic display system. The general design philosophy that guided the conceptual design is discussed first, followed by a description of the system components and their functions. The final portions of this section describe the operation of airborne and mission-planning control-display units. Because the control-display units designed for operation of the ground-based and aircraft-mounted systems are unusual, and because their operability is critical to the utility and acceptability of the systems, extensive descriptions of these units are provided. Descriptions of the operation of these units also form the framework for summaries of aviator requirements, present deficiencies, and system capabilities.

DESIGN PHILOSOPHY

The design of the system was guided by certain requirements, assumptions, and criteria. These factors are discussed below in terms of general guidelines and human factors engineering principles.

GENERAL GUIDELINES

In order to limit design options to those applicable to the development of a CGTD that is both valuable and practical for Army aviation use, certain generally agreed-upon criteria were employed in the evaluation of alternative design features. Brief discussions of these general guidelines follow.

Meet functional requirements. The most important guideline is that CGTD features must meet the functional requirements of Army aviators as defined by existing task analysis data (e.g., Rogers & Cross, 1979), and by data from the interviews and observations conducted during this project. The CGTD should meet these requirements at least as well as paper maps, and in most respects should be

superior to paper maps in providing the required information in the most directly usable form.

Provide a conceptual design. The design presented in the final report should be a conceptual design showing the required features of the system, the types of displays and controls recommended, and the operational procedures. Final specifications for hardware (such as materials, dimensions, reflectances, control resistances, display brightnesses, etc.) should be provided during subsequent syst. development efforts.

Ensure technical feasibility. The hardware and software requirements of the CGTD system should all be within the state of the art. Furthermore, most of the hardware required should be available "off-the-shelf," either as parts or, when possible, as complete system components.

Consider size and weight limitations. Preliminary analyses should indicate that an aircraft-mounted system of the recommended type could be designed to occupy an acceptably small cockpit area and could weigh 30 pounds or less. The ground-based mission-planning system could be larger and heavier to meet its additional requirements, but should be easily transportable for TOC use.

Consider field worthiness. Although the CGTD is a computer-based system, the recommended components should be ruggedizable for operation in the unforgiving tactical environments to which they would be exposed.

Minimize additional manpower requirements. The CGTD should be designed for simplicity of use. Incorporation of the CGTD into tactical units should not require the creation of a new military occupation specialty (MOS), and training time required for the CGTD's effective use should be minimal. Maintenance requirements should be minimized by employment of replaceable modules.

Provide broad utility. The system should be designed to be useful in all types of Army helicopters, and for all types of missions. Although it should be designed primarily for NOE flight in the high-threat environment, it should also be useful for other flight modes and requirements. It should be valuable in summarizing battlefield intelligence, in tactical decision-making, in communication, in mission planning, and in navigation.

Provide flexibility. The CGTD conceptual design should provide three types of flexibility. First, it should be configured to be useful as a versatile experimental tool so that the various features and characteristics of a prototype may be evaluated before fielding. Second, the CGTD should provide multiple methods of data entry and modes of display, so that the user may select those which seem most natural or useful at a given moment. Third, flexibility should be provided by an add-on capability. If additional requirements are defined in the future, hardware components should not be affected--only software supplements should be necessary.

HUMAN ENGINEERING PRINCIPLES

The design of interactive computer-graphic systems, like any human engineering design activity, is a subjective, creative process. For this reason, it is seldom possible to formally structure the methodological steps by which functional requirements data are translated into a conceptual design. However, analyses employing various human engineering principles and criteria are used throughout the process to evaluate the adequacy of design alternatives. Because these analyses are conducted in order to identify design features that violate human factors engineering principles, it is easier to recognize inappropriate design than correct design. Thus, the principles and criteria serve not to guarantee the attainment of some ideal design, but to eliminate design features that are likely to result in higher human error probabilities, longer task performance times, and more extensive training requirements.

The human engineering principles and criteria employed in the design of the CGTD are too numerous to be listed here. However, in order to clarify the nature of the design philosophy, examples of some of the more important principles are provided below:

- Information should be presented in the most directly usable form. The operator should not be required to perform mental computations, translations, or interpolations.

- The associations of controls and displays should be obvious to the operator through proximity, spatial arrangement, coding, or other techniques.

- The operator should be provided with immediate feedback information on the adequacy of his inputs and on the system's interpretation of the operator's intentions.

- Control-display movement relationships should be compatible with the operator's expectations.

- The arrangement of functionally similar or identical displays and controls should be consistent from panel to panel throughout the system.

- Controls and displays which are employed together, or in predictable sequences should be grouped together and arranged to facilitate their use.

- Labels should be as concise as possible, but not so brief as to introduce ambiguity or require memorization of unfamiliar words or abbreviations.

- Interactive computer systems should provide "prompting" messages to help lead users through operational sequences. Such messages, however, should not interfere with the activities of operators who do not require such assistance.

- Interactive computer systems should provide a MENU display--a "home base" to which the operator can return from any point in the control sequence in order to select a different transaction.

These, and many other principles and criteria were employed in guiding the development of the conceptual design. When detailed design of the CGTD begins, the application of additional (and much more specific) human engineering criteria will be necessary in order to assure that each display, control, and dialogue element is optimized for the human operator.

SYSTEM COMPONENTS AND THEIR FUNCTIONS

The CGTD is composed of two major subsystems: the airborne system and the ground-based system. The ground-based system includes all of the features of the airborne system and has additional capabilities for mission planning and database editing. Hereafter, this ground-based element will be referred to as the Integrated Mission-Planning Station (IMPS) when it is necessary to discriminate between this element and the airborne CGTD subsystem. The various components of the system, their purpose, and some of their characteristics are described in the following paragraphs. This description includes only the basic attributes of

components with which aviators interact--a more complete description of tentative engineering solutions for the realization of such a system has been provided by Shupe (1981).

THE AIRBORNE CGTD COMPONENTS

As shown in Figure 14, the aviator interacts with four airborne CGTD components: a color CRT, a magnetic tape loader, an airborne control-display unit, and a position-indicator control.

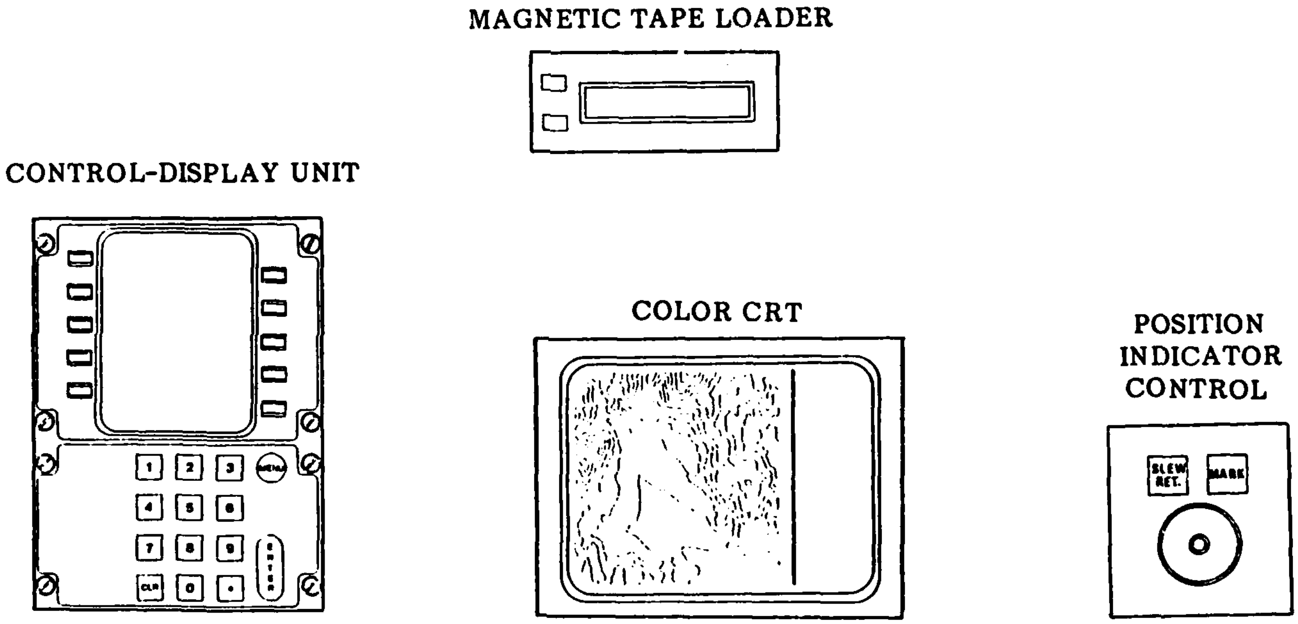

Figure 14. The airborne computer-generated topographic display components.

Color CRT

A color cathode ray tube is raster-scanned to display topographic and tactical data in the aircraft. The information displayed depends on the aviators' selections. Navigation sensor data, augmented with a terrain correlation technique, are used to identify the aircraft's current position for display on the CRT. A digital map-generation subsystem permits the display to translate and rotate in response to aircraft motion. Because the topographic data are presented in a square format, and most CRT's have a rectangular shape, one-fourth of the screen area may be used for presentation of supplementary data, should such a feature prove useful.

Magnetic Tape Loader

The magnetic tape loader consists of a small electronics unit and a removable hermetically-sealed cassette. The cassette provides storage for topographic, intelligence, operations, and mission-planning data. The geographic area stored on a single cassette is envisioned to be 100 by 100 kilometers--roughly 16 times the area shown on a standard 1:50,000-scale map.

Airborne Control-Display Unit

The airborne control-display unit (CDU), shown in Figure 15, is an integrated, multi-purpose module which provides the aviator with his primary means of exercising the extraordinary flexibility built into the CGTD system. The upper portion of the CDU is composed of a small monochrome CRT that displays 12 lines of data. The top line is reserved for advisory data, and the bottom line is used as a "scratch pad" to echo keypad entries. The central 10 lines may be used for data display, prompting messages, or labels for the adjacent line select keys. The labels change to indicate the current function of each line select key because the functions of any given line select key will differ depending upon the type of transaction in progress. The versatility of this display-control concept is demonstrated in subsequent pages of this section. Not only does it provide an easily understandable method for leading the user through operational sequences, it also eliminates the need for scores of single-purpose control and display elements.

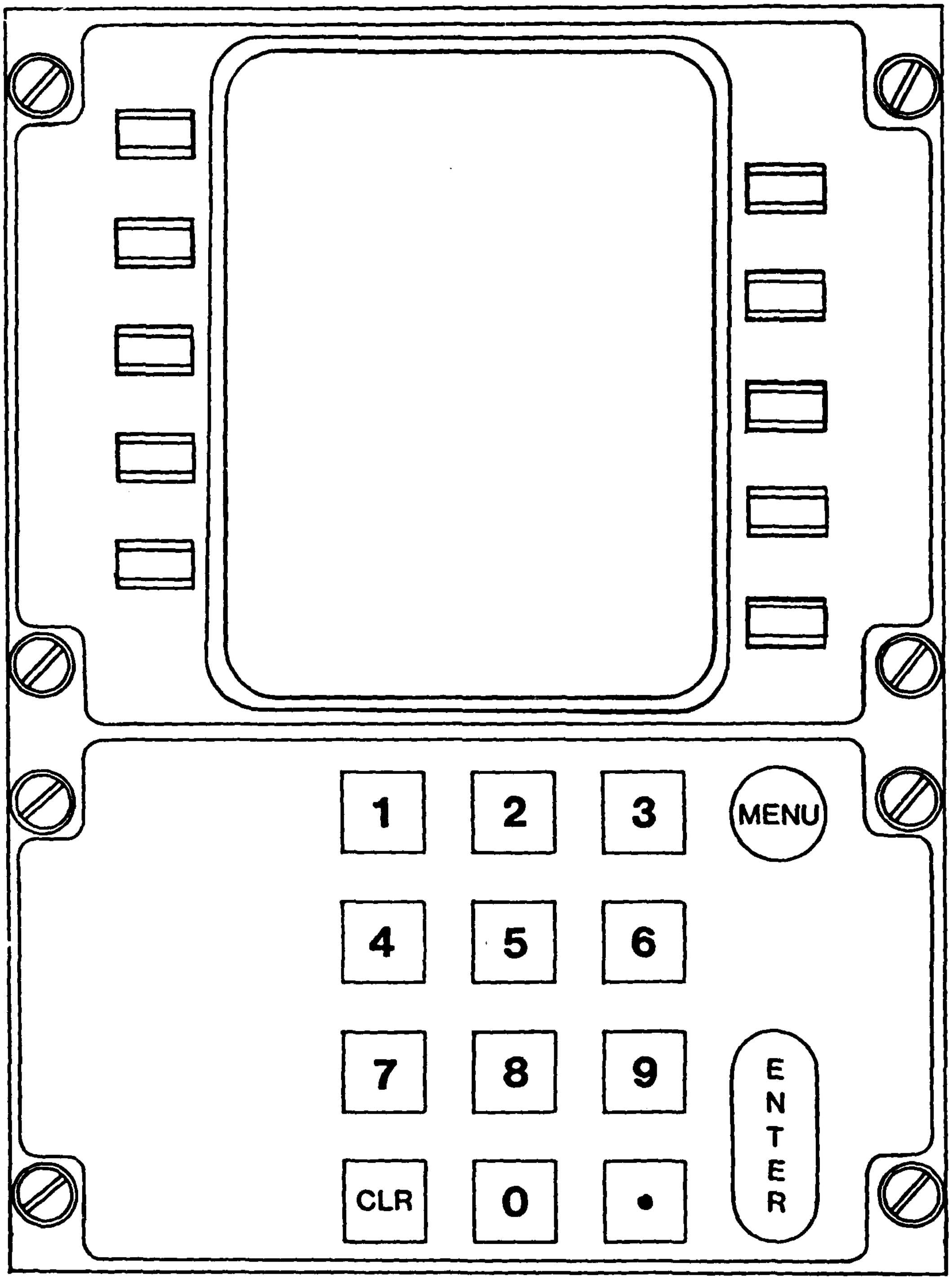

Figure 15. The Airborne Control-Display Unit (CDU).

The lower portion of the CDU provides a keypad and ENTER button for input of numeric data. The CLR button, when pressed once, clears the last digit shown in the scratch pad. A second press clears the scratch pad completely. The MENU button is used to call the display page that presents the initiation points for all transactions with the CGTD. Other controls likely to be located on the CDU (but not shown in Figure 15) are a CRT brightness control, a power on-off switch, and a "zero" switch to erase secure information.

Position-Indication Control

The position-indication control (PIC) is composed of a miniature joystick and two adjacent pushbuttons. An example of a possible configuration of this device is shown in Figure 16. The joystick is used to slew the map, to control a position-indicating cursor, and for other spatially oriented tasks. The joystick is a force-operated, first-order control device such that the harder the stick is pressed, the faster the motion of the controlled element. This type of control device offers the dual advantages of rapid movement and fine positioning capabilities. Use of the push-buttons is described later in this section.

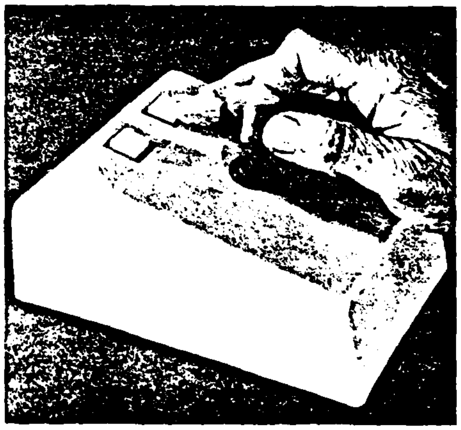

Figure 16. Potential configuration of the PIC.

THE INTEGRATED MISSION-PLANNING STATION COMPONENTS

The IMPS components include those of the Airborne CGTD, described above. As shown in Figure 17, the IMPS also provides a tape-copying unit, a light pen, an alphanumeric keyboard, and map overlay digitizing equipment. The CDU employed by IMPS is identical to that employed in the aircraft except that additional software is provided for performance of special IMPS tasks.

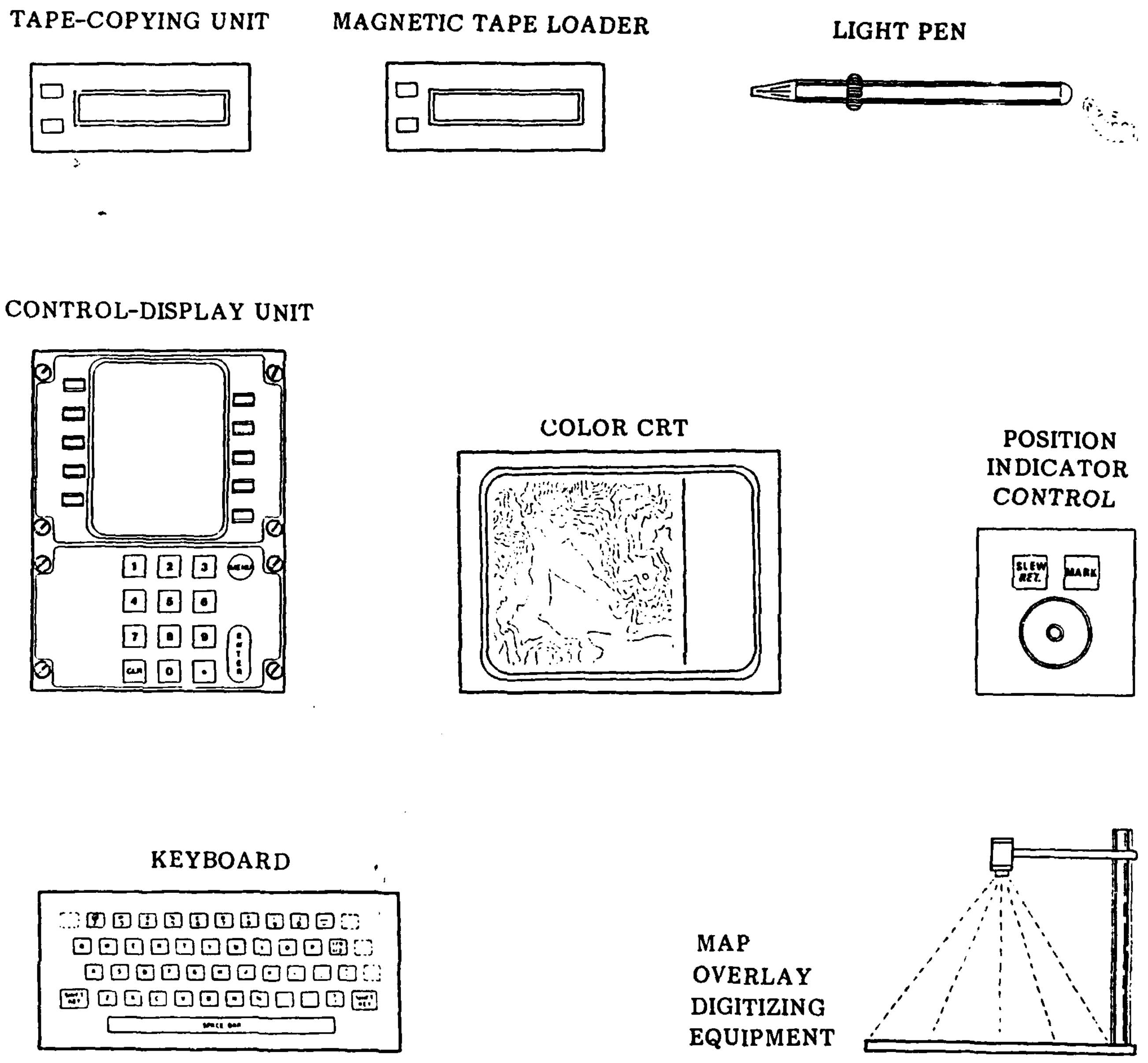

Figure 17. The integrated mission-planning station components.

Tape Copying Unit

A tape copying unit is provided for rapid duplication of the tactical data entered on master tapes by intelligence and operations personnel. This unit is used to provide aviators with cassettes showing the most current battlefield situation data.

Light Pen

A light pen is provided for use in editing and annotating the digital data. A major advantage of a light pen is that it requires almost no operator training for its use because the hand-eye coordination employed is the same as that used in drawing with a pencil. Because aviators draw upon their paper maps, a light pen is provided to permit the analagous "drawing" on the CRT map display. An example of a light pen in use is shown in Figure 18.

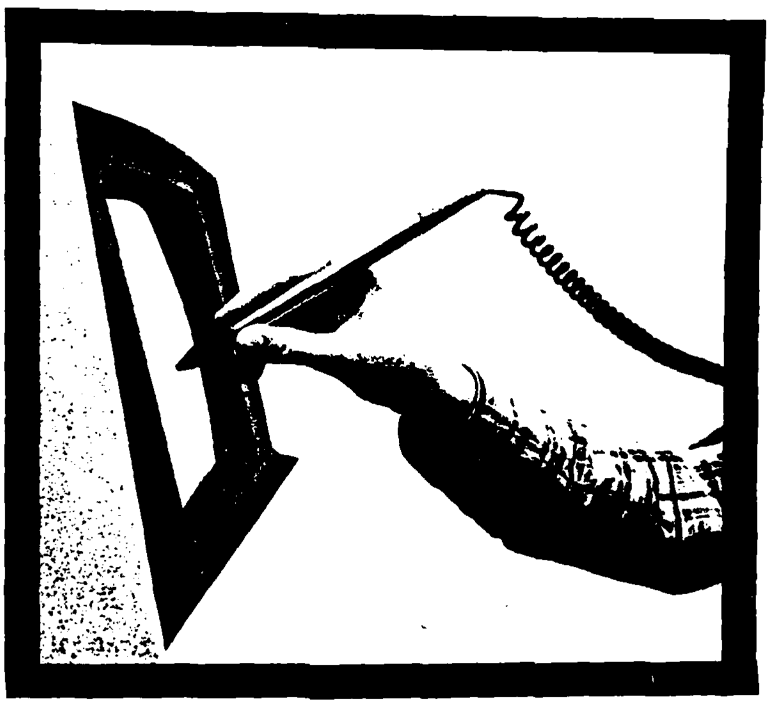

Figure 18. A light pen in use.

Alphanumeric Keyboard

Although most map editing and annotation will use point, line, and area symbols, the use of words to retrieve symbols, or the presentation of words on the display will be required on certain occasions. A standard keyboard is provided for such entries.

Map Overlay Digitizing Equipment (MODE)

The function of the MODE is to digitize acetate overlays corresponding to standard paper topographic maps. This capability is necessary because the transmittal of geographic information by way of overlays is a standard procedure in Army operations. Furthermore, the revision of acetate overlays on a situation board, and the periodic digitization of these overlays may provide the most efficient means of updating the data base when a rapid series of after-action debriefings is required. The MODE consists of a table upon which the overlays are placed, and a small TV camera with associated electronic equipment. The use of the MODE is described subsequently in this section of the report.

OPERATION OF THE AIRBORNE SYSTEM

This subsection of the report describes the procedures employed in operation of the airborne CGTD system. The procedures are defined for nine sets of functions performed by the system. The requirements for each set of functions, and the present deficiencies in providing these functions are briefly described, followed by a short discussion of the capabilities of the CGTD system for meeting the requirements and overcoming the deficiencies.

The specific procedures for operation of the system are presented by showing the changing display "pages" on the CDU and examples of changes in the map display resulting from inputs to the CDU or the PIC. A single CDU page is used for initiating all procedures. This page, called the MENU page, is shown in Figure 19.

The labels on the MENU page identify the nine sets of functions performed by the airborne system, plus an auxiliary for expansion. Pressing the line select

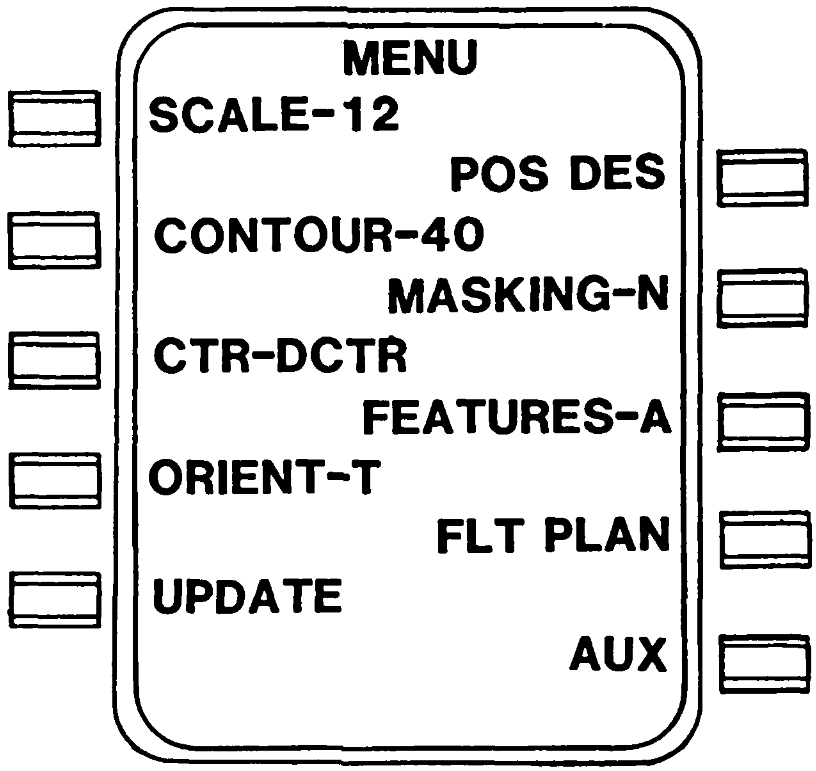

Figure 19. The MENU page of the Airborne CDU.

key adjacent to one of the labels initiates the procedural sequence required for performance of that function. In the subsequent descriptions of CDU use, a circle around one of the line select keys indicates use of that key.

This subsection and the following subsection describing operation of the IMPS system present a great deal of information in a relatively concise manner. A casual scanning of these subsections may result in the impression that the operation of these systems is somewhat complex. However, scrutiny of individual functions reveals that the CDU pages carefully guide the aviator through the procedures, yet permit him a comfortable margin of flexibility so that the dialogue is smooth and natural. The pages are designed to fulfill functional requirements with a minimum number of control activations but do not place a significant memory burden on the aviator. Furthermore, the system is designed so that

constant manipulations are not required--the aviator sets up the system for optimal performance of required tasks and periodically exercises its special functions as desired.

In the subsequent paragraphs, operational procedures are described for the following nine sets of functions:

Map Scale
Map Contour
Center-Decenter
Map Orientation
Position Update
Position Designation
Masking and Intervisibility
Feature Selection
Flight Plan

MAP SCALE

Requirements. Aviators attempt to obtain maps of several different scales for use in the planning and conduct of missions. Maps in 1:250,000 scale, valued for their wide area coverage, are useful in depicting the overall battlefield situations. Maps in 1:25,000 scale show small areas, but provide fine detail for study of the objective or features along the flight route. Maps in 1:50,000 scale are typically used for navigation at NOE altitudes because they provide the minimum required detail for correlation of map and terrain features.

Present deficiencies. Although NOE flight requires the use of large-scale maps (1:50,000 or larger), only a small percentage of the earth's surface is currently mapped in large scale. Attempting to use small-scale maps (1:250,000 and 1:500,000) is almost certain to lead to disorientation during NOE flight. Even where large-scale maps are available, however, their use in the cockpit is often awkward because many different map sheets may be required for a single mission.

CGTD capabilities. The CGTD data base may be employed to portray the terrain in any of several scales selectable by the aviator. During mission planning, small-scale portrayal could be used for overall route selection, alternated with large-scale portrayal for scrutiny of specific terrain features. During mission

conduct, the map scale could be rapidly changed for greatest utility given the aircraft speed, the view of surrounding terrain, the information necessary for orientation, and the desired look-ahead distance. The size of the data base (100 x 100 km) is independent of map scale, so that "flying off the map" is no longer a drawback to large-scale map use.

CDU operation. When the MENU page is displayed, pressing the line select key labeled "SCALE" calls the scale selection page, as shown in Figure 20. Pressing any of the labeled keys on the scale selection page causes the map display to change to the selected scale. Figure 21 provides an example of change from 1:50,000 scale to 1:25,000 scale. The scale options are labeled in two ways. At left, the scale distance across the map display is shown. Adjacent to this label is the equivalent scale fraction, for reference. An asterisk shows the currently displayed scale. In addition, a number beside the page title indicates the scale. This number is also displayed beside the SCALE label on the MENU page. The aviator may continue to change scales until he elects to return to the MENU page. The scale last selected will then be maintained on the display. Selection of map scale will also affect the display of contour interval and terrain features, as discussed subsequently in this subsection of the report.

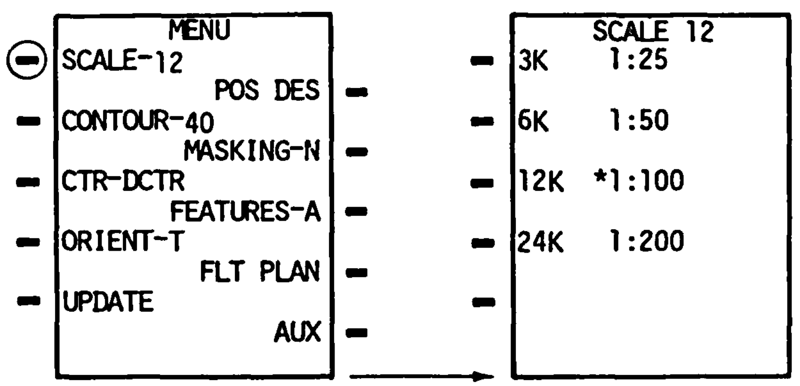

Figure 20. Scale selection by CDU.

1:50,000
Scale

1:25,000
Scale

Figure 21. Example of CGTD scale change. The inset box in the top section shows the area covered in the bottom section.

MAP CONTOUR

Requirements. For Army aviators, terrain relief--the shape and height of landforms--is probably the most important class of information on a map. Landforms are stable over long periods of time, are often unique in appearance, and are nearly always discernible. These considerations make landforms the primary reference for geographic orientation. Furthermore, terrain relief has great tactical significance for military operations in general, and NOE flight in particular. It is essential for all types of missions that aviators be able to extract terrain relief information from contour data presented on maps. Terrain relief is depicted on most topographic maps through the use of contour lines.[3] The contour line technique is the only terrain encodement scheme which meets the severe requirements of NOE navigation: depicting very large elevation ranges while maintaining the precision required for referencing relatively small terrain features.

Present deficiencies. Unfortunately, the perceptual task of relating contour lines on a map to the terrain relief on the ground is the most difficult aspect of map interpretation during NOE flight. Even experienced Army aviators commonly encounter difficulty in performing contour interpretation (Rogers & Cross, 1978, 1980). This difficulty tends to result in geographic disorientation and limits the ability of aviators become reoriented.

The ideal contour interval for landform portrayal depends upon the dimensions of the features, the steepness of their slopes, and the precision required by the aviator. A small contour interval is useful for defining relatively small, flat terrain features. The same contour interval cannot be used for steep terrain features because the lines would abut and form dark areas devoid of information. The contour interval on paper maps, however, is fixed. The cartographer must select a compromise interval (although supplementary contours are sometimes added).

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[3]For a complete discussion of the characteristics of contour lines and other terrain-relief encodement schemes, see Cross, 1977, pp 26-41.

To aid the interpretation of contour lines, some topographic maps have added shaded relief. This shading, however, is usually manually rendered with an airbrush and reflects a simplified version of the cartographer's interpretation of the relief. The accuracy and precision of this technique is questionable, and the time required for its application is considerable. Furthermore, it is possible that such shading may adversely affect map legibility.

Another attempt at aiding the aviator's visualization of the terrain is the "elevation guide." The elevation guide is a very small scale map (found in the margin of most topographic maps) that uses three or four unique shades of gray to define the layers between selected elevation contours. The elevation guide, however, is provided only to indicate the overall high and low terrain of the mapped area and cannot be used as a precise navigational earth reference.

CGTD capabilities. The CGTD system is capable of displaying any contour interval selected by the aviator. The contour interval can be quickly shifted to meet the changing requirements for precision and to improve the ease of contour interpretation. The general lay-of-the-land, or the configuration of specific landforms, may be carefully examined by selection of the appropriate map scale and variation of the contour interval. The CGTD may also be employed to produce extremely precise relief shading without incorporating human errors of interpretation. The shading algorithm developed at ARADA (Shupe, 1981) produces an extremely realistic representation of a three-dimensional landform from elevation data, and will greatly reduce the information processing burden imposed upon the aviator by the contour interpretation task. In addition, the CGTD provides the aviator with an elevation guide capability. Rather than employing a separate, small-scale depiction, the entire map area is used to display the gray-shaded contour bands so that the guide may be used in conjunction with data providing precise navigational reference points. Furthermore, the aviator can adjust the guide bands in order to optimize the utility of this feature.

CDU operation. When the MENU page is displayed, pressing the line select key labeled CONTOUR calls the contour selection page, as shown in Figure 22. If the aviator wishes to change the contour interval, he presses the key labeled ENTER C INT and uses the keypad to determine the interval in meters. The interval currently depicted on the color CRT is shown beside the page title and beside the CONTOUR label on the MENU page. Figure 23 shows examples of the effects of entering various contour intervals via the CDU. The contour interval setting is specific to each displayed map scale so that scale changes automatically include contour interval changes.

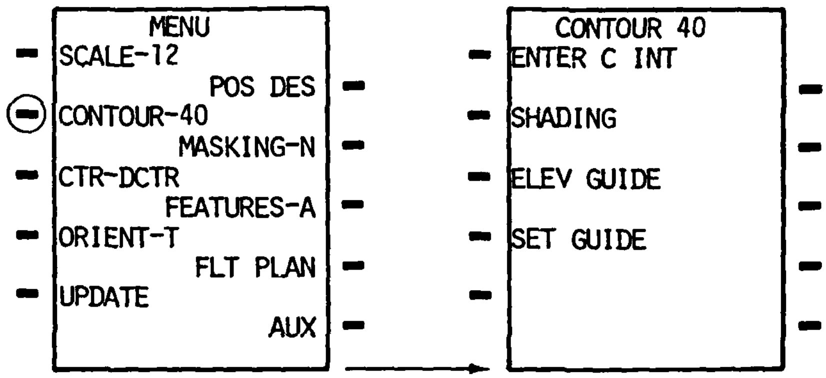


Figure 22. Contour selection by CDU.

Figure 24 shows examples of the enhancement of contour interval relief portrayal by the shaded relief and the elevation guide options. Line select keys on the contour selection page may be pressed to display these options. A second key press deletes the feature. The two features are mutually exclusive so that selection of one automatically deletes the other. Changing the characteristics of the elevation guide is initiated by pressing the line select key labeled SET GUIDE, as shown in Figure 25. The CDU shows the present settings and permits the aviator to enter the maximum elevation to be included, and the elevation range (band-width) of the gray bands. These two settings provide the aviator with considerable flexibility in use of the elevation guide. Up to eight shades of gray may be employed--distributed over the entire elevation range, or limited to any particular

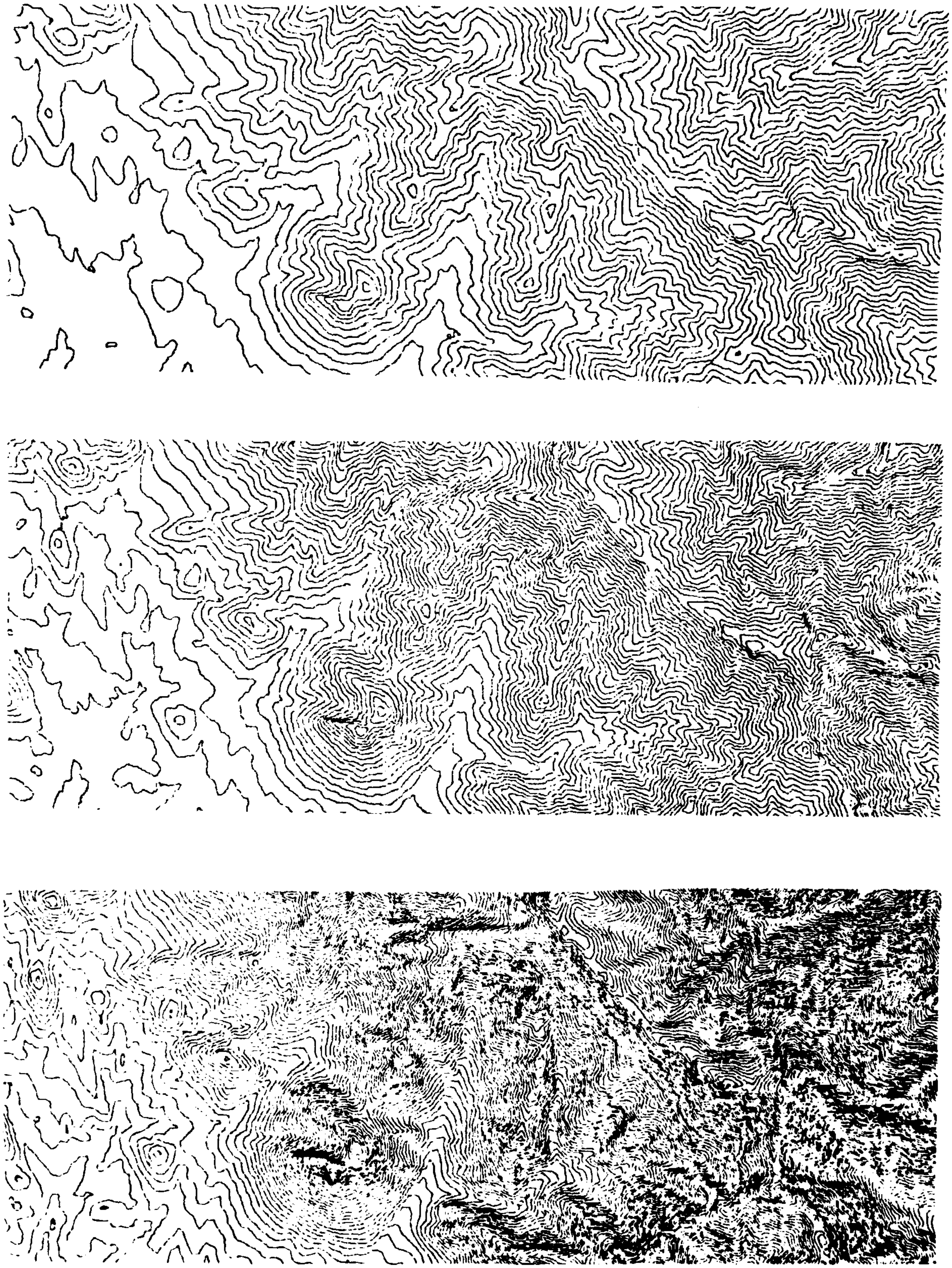


Figure 23. Examples of terrain portrayed by three different contour intervals: top, 36 meters; center, 24 meters; bottom 12 meters.

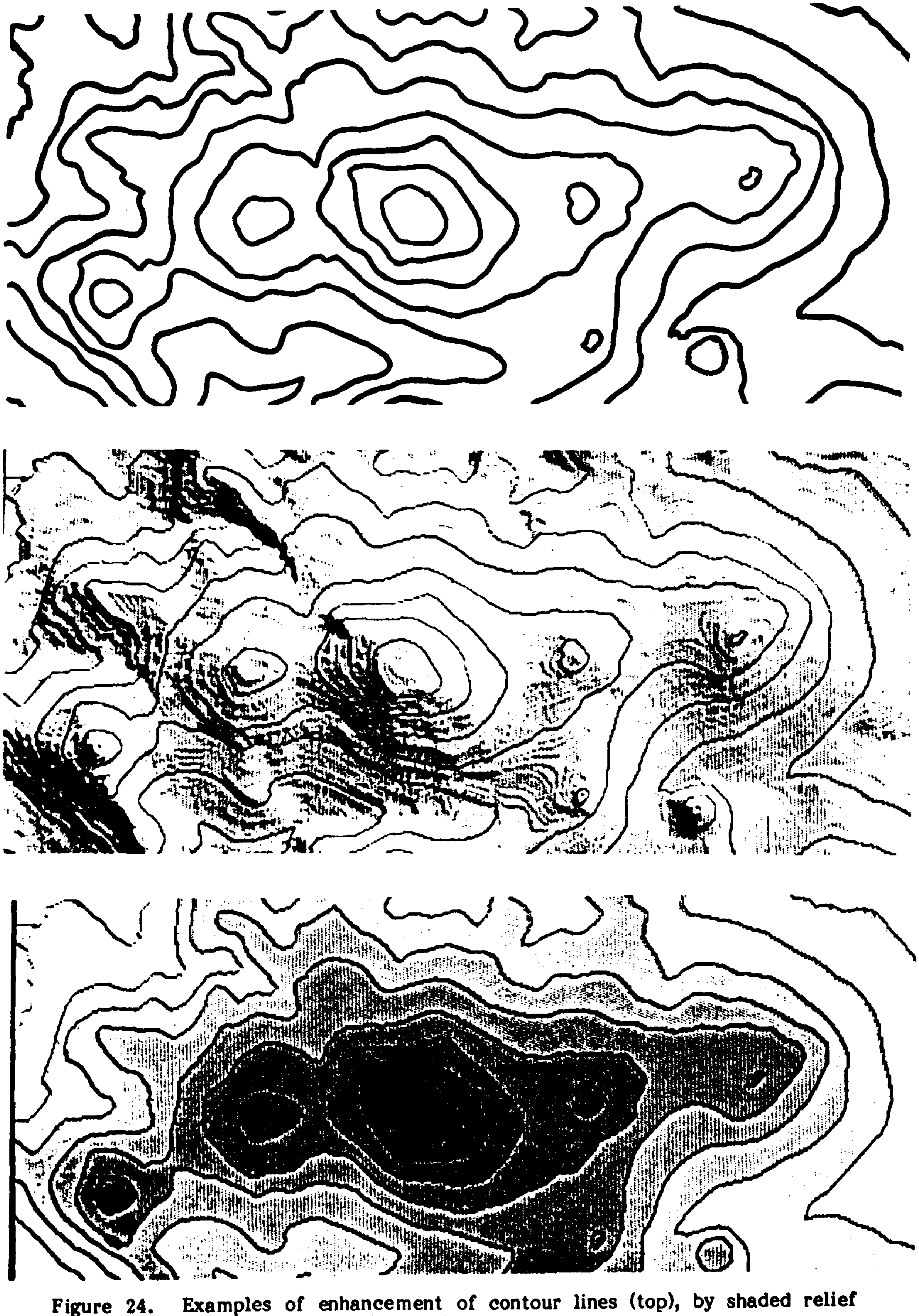


Figure 24. Examples of enhancement of contour lines (top), by shaded relief (center), and the elevation guide (bottom).

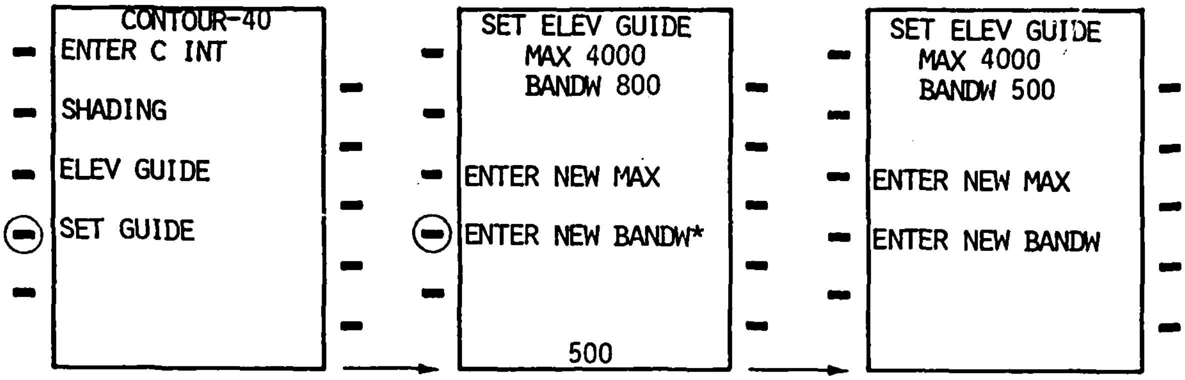


Figure 25. Setting elevation guide by CDU.

range of interest. To perform the settings, the aviator presses the key labeled ENTER NEW MAX or ENTER NEW BANDW, and uses the keypad to determine these settings. Like the contour interval setting, the elevation guide settings are maintained in system memory and are specific to each map scale.

CENTER-DECENTER

Requirements. The aviator is concerned not only with the position of his aircraft on the map, but with the positions of the surrounding military units, obstacles, checkpoints, and landforms. Although the primary area of interest is usually forward of the aircraft, the aviator must also be able to examine mapped data to the sides and to the rear of the aircraft in order to annotate the map with positions of bypassed targets, downed friendly aircraft, or other tactical data. In addition, it is sometimes necessary to study sites at some distance from the aircraft's present position--for example, the area surrounding the mission objective.

Present deficiencies. Paper maps provide good flexibility for examination of areas adjacent to, or distant from the aircraft. In the cockpit, however, the required folding, unfolding, and refolding of maps often becomes awkward.

CGTD capabilities. The CGTD incorporates several features that enable the aviator to conveniently study portions of the data base near to or distant from the aircraft's present position. First, the aviator may select the location of the aircraft's present position indicator--either centered on the display screen to permit portrayal of the terrain surrounding the aircraft, or decentered to provide maximum look-ahead distance. Second, the CGTD system will display the area surrounding any position in the data base designated by the aviator. Third, the displayed area may be changed by slewing the windowed area to increase the viewing distance in any direction.

CDU operation. When the MENU page is displayed, pressing the line select key labeled CTR-DCTR calls the center-decenter selection page, as shown in Figure 26. The results of pressing the key labeled AC CTR or AC DCTR are shown in Figure 27.

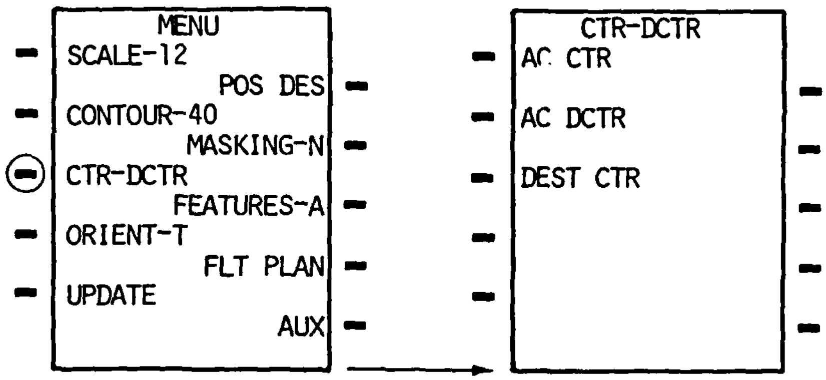
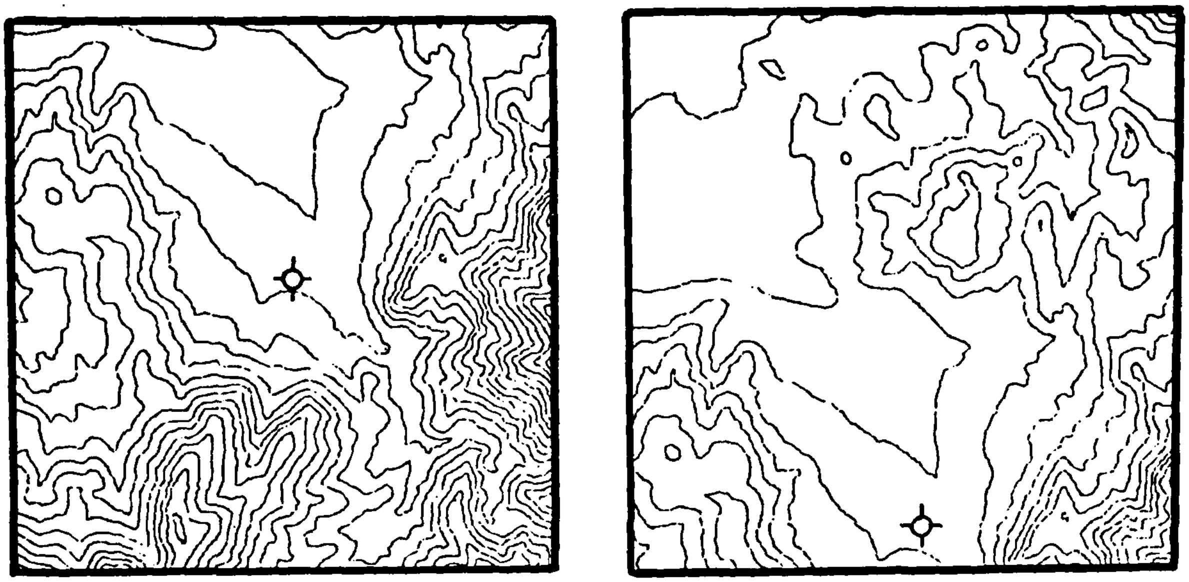


Figure 26. Selecting center or decenter by CDU.

To view the area surrounding the flight destination (or any other point in the data base), the aviator presses the line select key labeled DEST CTR. As shown in Figure 28, this activation calls the destination center page. If a particular destination has previously been entered, the coordinates of this position are indicated on the CDU, and the map display slews or regenerates to depict the selected destination. If the aviator wishes to view some other area, he presses the key labeled ENTER NEW DEST and enters the coordinates of the desired position on the keypad. Upon depressing the ENTER button, the new coordinates move



CENTERED DECENTERED

Figure 27. Effects on the map display of selecting the centered or decentered mode.

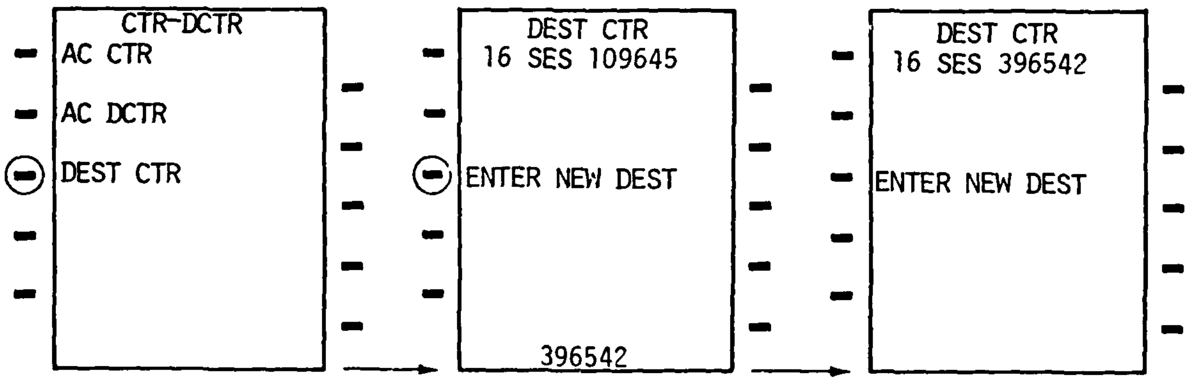


Figure 28. Selecting the destination center mode by CDU.

from the scratchpad line to the advisory line of the CDU, and the map display presents the selected area. A unique symbol identifies the selected position on the display center. In this mode, the map does not move. However, if the map scale and aircraft distance are such that the aircraft is within the viewed area, the aircraft symbol appears at the appropriate position and moves across the screen in accordance with the aircraft's flight relative to the centered position. Figure 29 shows the display in the destination-centered mode with an aircraft symbol nearby.

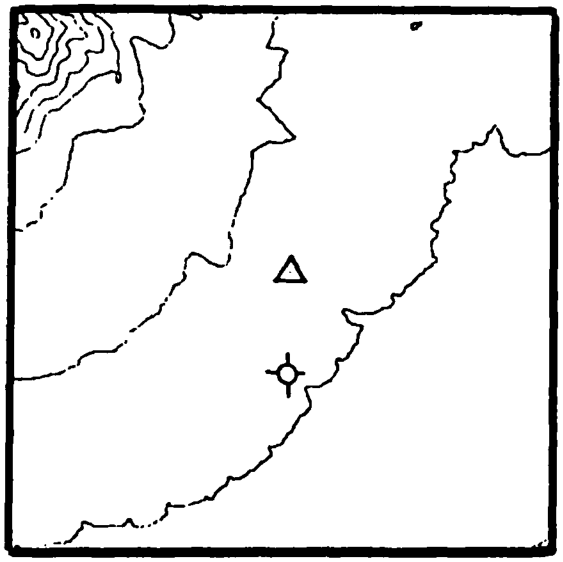


Figure 29. Effect on the display of selecting the destination-centered mode.

In any of the three modes described in this section, it is possible to increase the viewing distance in any direction by slewing the map. The total viewable area at any moment is expected to be approximately four times that presented in the display window. For example, in Figure 30, the dotted lines show the viewable area and the solid-line box shows the windowed area. The dashed line boxes show two potential window areas exposed by slewing the map.

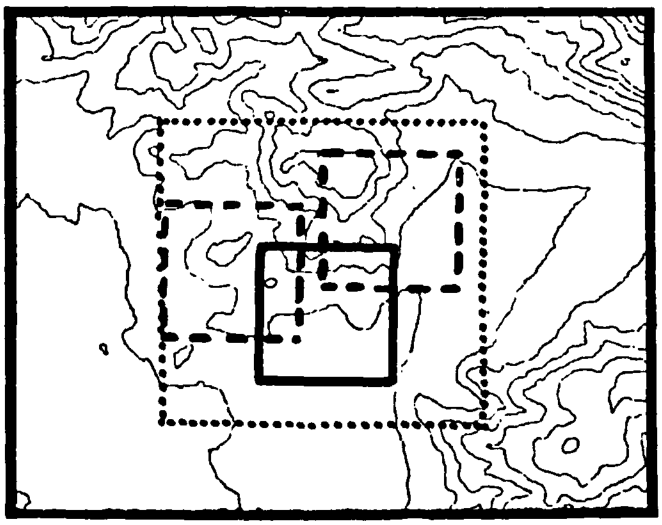


Figure 30. Examples of viewable areas exposed by slewing.

PIC operation. Slewing is achieved by activation of the Position Indication Control (PIC) shown in Figure 31. This control is used for a number of purposes, described in other sections of this report. In every case, where not otherwise specified, however, the joystick is used to slew the map, thus providing an immediate method for expanding the viewable area. By pressing the SLEW RETURN button, the aviator causes the map to slew directly back to the aircraft-centered, aircraft-decentered, or destination-centered position. Use of the MARK button annotates the map with a symbol at the aircraft present position. This and other annotations are discussed in subsequent sections of this report.

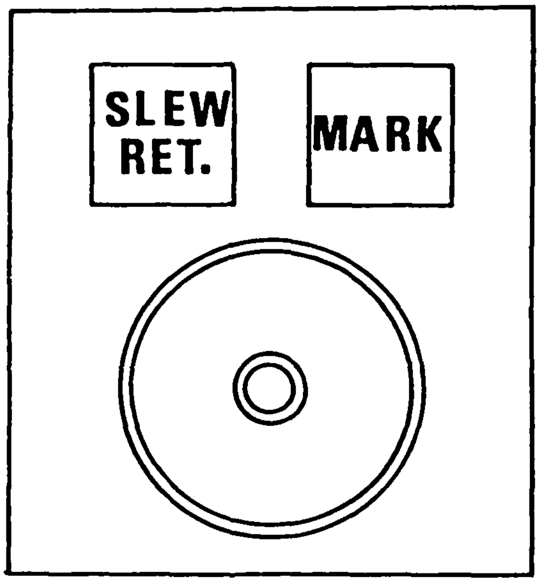


Figure 31. The Position Indication Control (PIC) unit in plan view, showing pushbutton labels.

MAP ORIENTATION

Requirements. The majority of aviators prefer to orient the map so that the spatial arrangement of the map features is congruent with the arrangement of topographic features on the ground. This map orientation simplifies navigation by terrain referencing because it minimizes left-right confusions. A small proportion of aviators, however, prefer to maintain the map in a constant orientation and

mentally transpose the spatial relationships of map and ground features. Still others prefer to turn the map to the cardinal direction nearest the aircraft's planned or actual flight heading.

Present deficiencies. Although paper maps are easily turned to any orientation, determining their correct orientation can be confusing when the aircraft is following a sinuous course--as is often required for NOE flight. Because all of the alphanumeric information on a map (place names, spot elevations, grid line numbers, etc.) is oriented to be read when the map is north-up, some aviators attempt to alternate between north-up and heading-up map orientations, risking momentary disorientation with each change of map position. Others elect to maintain the north-up mode to reduce this source of confusion, even though the spatial relationships of map and terrain features are not optimal.

CGTD capabilities. The CGTD system is capable of providing any desired map orientation, and alternating among orientations at will, whether the aircraft is on the ground or in flight. The terrain correlation subsystem continues to function during any map orientation, moving the map past the aircraft's present position symbol in accordance with the aircraft motion over the ground. A map "freeze" capability is also provided to temporarily halt map motion for the cases in which a stabilized image will aid in examination of map details.

CDU operation. When the MENU page is displayed, pressing the line select key labeled ORIENT calls the map orientation page as shown in Figure 32. Pressing one of the labeled keys on the right side of the CDU orients the map with the selected cardinal direction upward. Pressing the TRK UP key causes the map display to show track-up, i.e., wind-corrected course upward. In helicopters, a stable track can be computed only when the aircraft is proceding at some given forward speed, probably about 10 knots (McGrath, 1976), so a heading-up capability must also be provided for use during hovering. The HDG UP key causes the display to rotate to a heading-up orientation. In order to select any arbitrary orientation, the aviator presses the BRG UP key. The called page permits selection of any desired bearing-up orientation via the keypad, as shown in Figure 33.

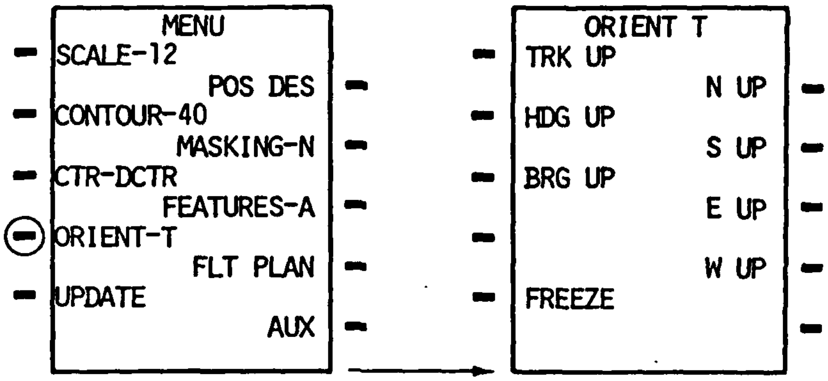


Figure 32. Map orientation selection by CDU.

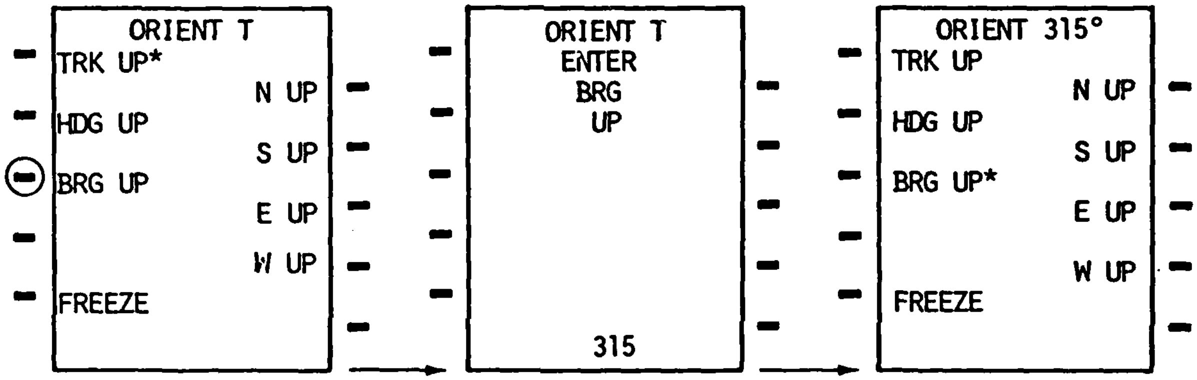
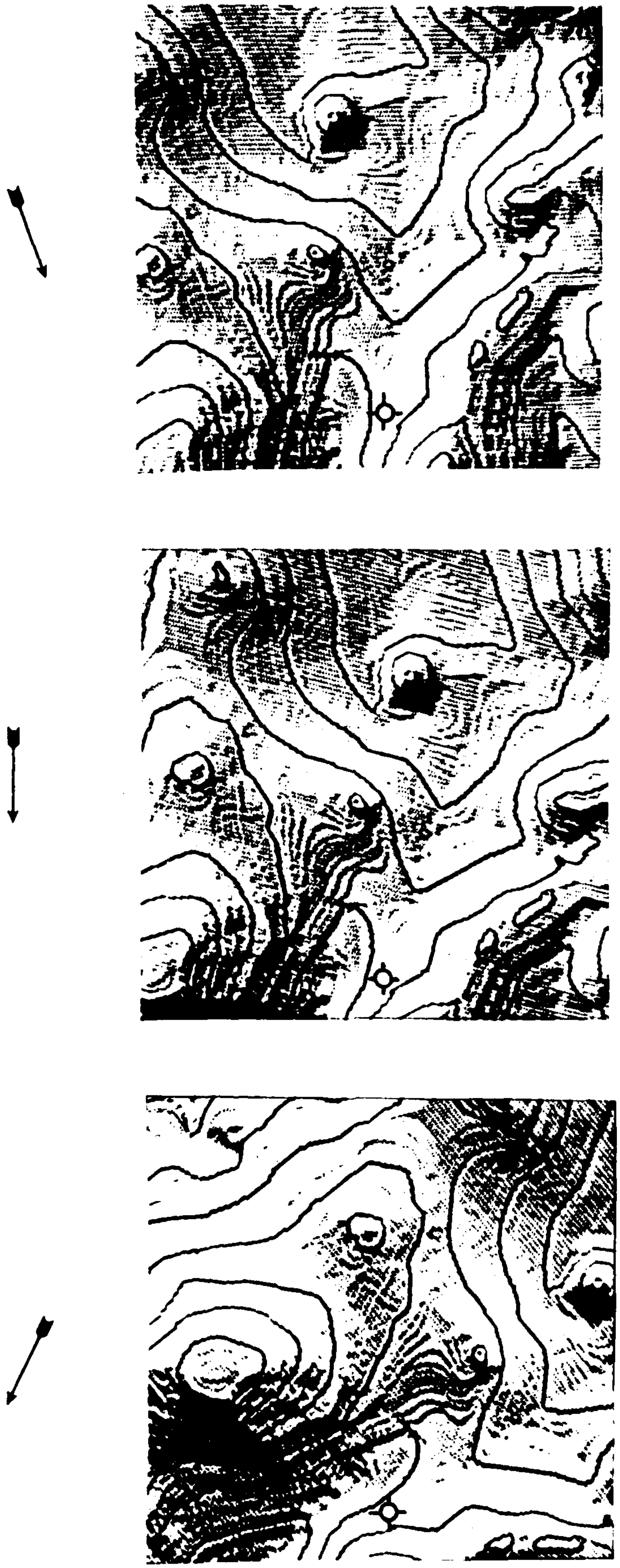


Figure 33. Entry of desired bearing-up by CDU.

Figure 34 shows the effect on the display of selecting three different map orientations. In segment b of the figure, the track-up mode has been selected and the map motion is downward, as shown by the arrow. The arrows in the other two segments show the direction of map motion when north-up or 315°-up orientations have been selected. In the decentered mode, the greatest look-ahead distance is achieved with the track-up orientation; in the centered mode, all orientations would provide the same look-ahead distance.

Pressing the FREEZE key stops the motion of the map in order to facilitate map study during flight. In the freeze mode, the terrain correlation subsystem continues to compute the aircraft's position, and the present position indicator moves across the stabilized map (similar to the destination-centered mode



a. NORTH-UP
(360°)

b. TRACK-UP
(340°)

c. BEARING-UP
(315°)

Figure 34. Examples of three different map orientations.

previously discussed). Pressing the FREEZE button a second time causes the map to resume motion and the present position indicator to return to its centered or decentered location on the display.

The orientation currently selected is shown by an asterisk beside the key label and by an initial or bearing beside the page title. This initial or bearing is also displayed beside the ORIENT label on the MENU page.

POSITION UPDATE

Requirements. Navigation at NOE altitudes requires continuous maintenance of orientation by identifying terrain features along the route and correlating them with features depicted on the map. Because of the aviator's limited view of the terrain, extremely reliable checkpoints may be available only intermittently. At these checkpoints, the aviator must "update" his estimated position on the map, reducing any accumulated error to a minimum. Although navigation during NOE flight is one of the most demanding tasks ever required of an aviator, there is no substitute for accurate position updating--inaccuracy leads to disorientation and mission failure.

Present deficiencies. Both anecdotal evidence and experimental data indicate that the average Army aviator is unable to consistently perform NOE navigation to the required level of accuracy. Furthermore, in Scout aircraft, navigation is often the responsibility of a crew chief who is insufficiently trained for this difficult task and may be unable to do more than recognize the most obvious man-made terrain features.

CGTD capabilities. The CGTD incorporates the most recent development in automated navigation--terrain correlation technology, such as that employed by "cruise missile" weapons. The system uses the digital elevation data, the ground clearance (determined by a radar altimeter), and doppler data to continuously update the navigation display. The system is expected to present the aircraft position with great accuracy. The aviator will have only to set the initial position of the aircraft, and (possibly) to make occasional correctic s enroute.

CDU operation. When the MENU page is displayed, pressing the line select key labeled UPDATE calls the update page as shown in Figure 35. As shown by the CDU, the aviator may update his position either by entering grid coordinates or by slewing the map with the PIC. An example of the latter method is provided in Figure 36. In the upper section of the figure, an arrow indicates a hill which the aviator recognizes as the actual aircraft position. Using the PIC, he slews the map so that the present position indicator is correctly placed, and presses the MARK button. An update at high speed may be simplified by pressing the FREEZE button on the CDU, slewing an upcoming feature under the present position indicator and pressing the MARK button as the feature is overflown. In this case, the map will resume motion when the MARK button is pressed.

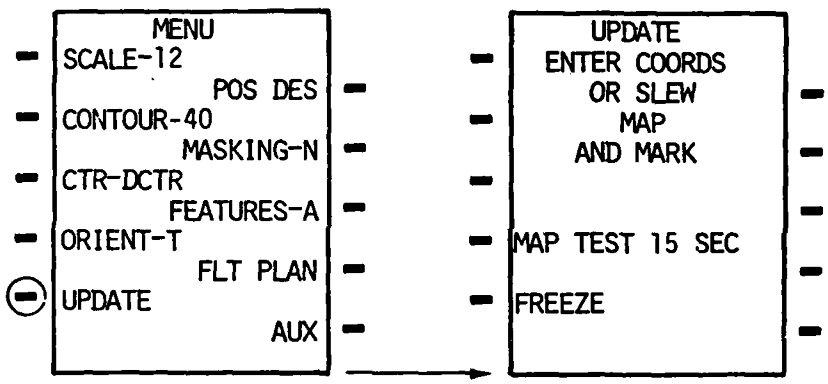


Figure 35. Initiating a position update by CDU.

It is likely that the computations performed by the terrain correlation subsystem can be adapted for maximum efficiency if the confidence of the update can be entered. For this reason, a position confidence page appears on the CDU after an update by coordinates or map slewing, as shown in Figure 37. The aviator indicates the confidence he has in the update by pressing the key on this page that is labeled with the error range best associated with the update. An asterisk appears beside the selection to indicate that the computer has received the input.

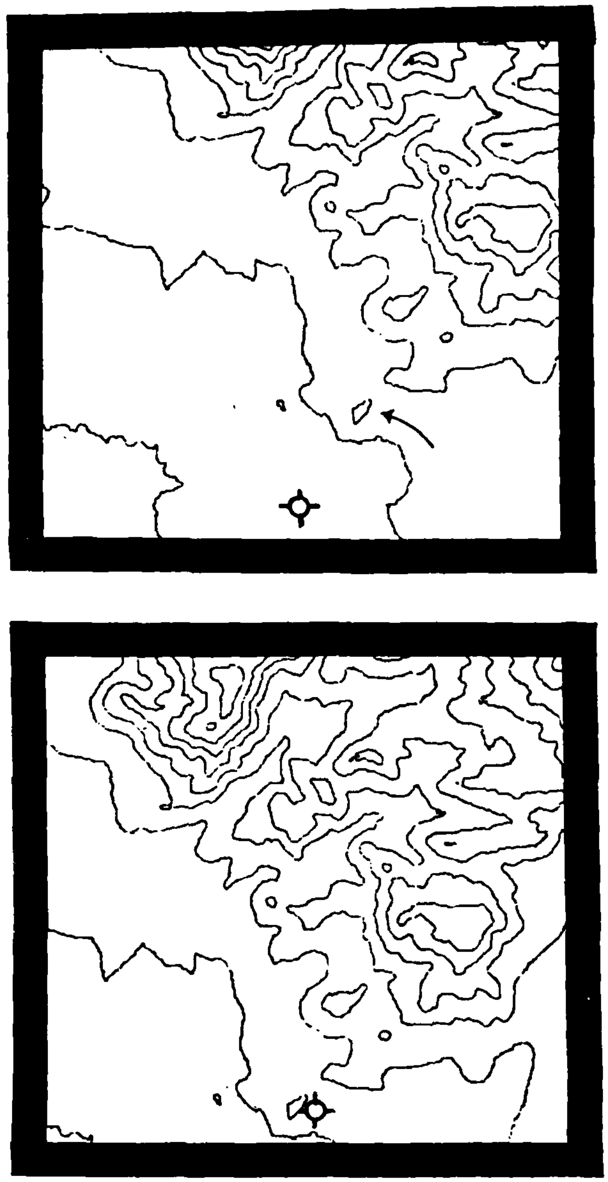


Figure 36. Slewing the map to update the aircraft position.

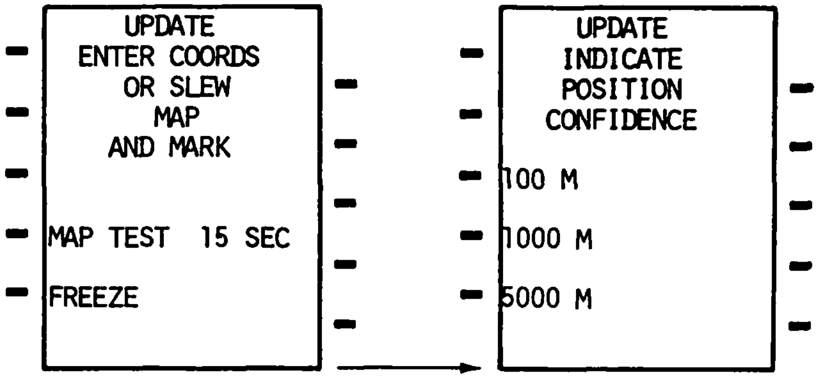


Figure 37. Indication of position confidence by CDU.

Also shown on the update page is the MAP TEST feature. Pressing the line select key beside this label initiates a series of computer self-checks that conclude with a GO or NO-GO message, as shown in Figure 38. The time required for the test is shown on the update page (15 seconds is hypothetical) to forewarn the aviator. Following test initiation, an "in-process" advisory is presented by the CDU, and a test abort button is provided to allow resumption of normal operations should they be urgently required. The final page indicates whether or not the system is properly functioning.

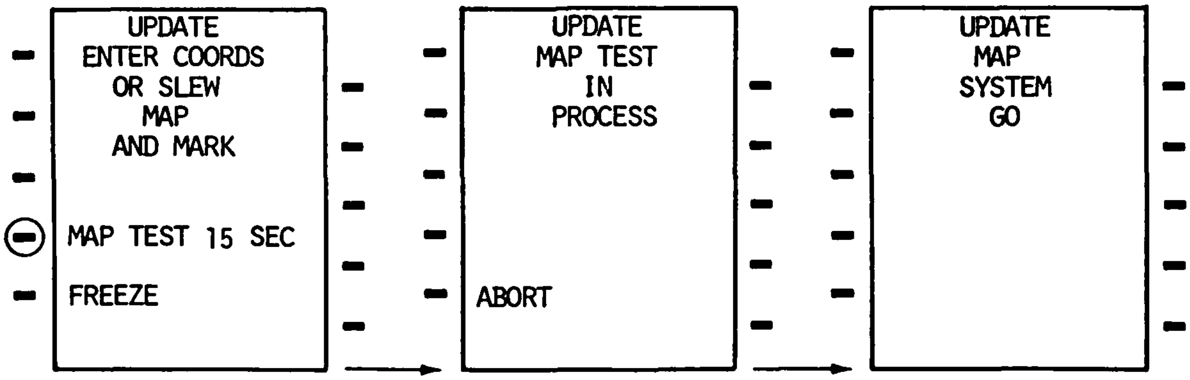


Figure 38. Map self-test initiated by CDU.

POSITION DESIGNATION

Requirements. All military activities are dependent upon the rapid and accurate transmisison of geographic data. The determination, recording, and communication of position designations are continually recurring requirements for Army aviators. Examples include handing off targets, calling for artillery support, requesting tactical air strikes, gathering battlefield intelligence data, specifying rendezvous points, coordinating battle team operations, performing resection for navigation checks, and identifying LZ's. Positional information is transmitted by simple grid coordinates, coded coordinates, preselected position code names, and range and bearing from known positions. Latitude and longitude is used for communicating positions to supporting tactical aircraft.

Another type of data often required regarding specific geographic positions is that of elevation. A primary use of elevation data is for terrain avoidance during conditions of limited visibility. Elevation data are also useful for navigation by terrain association through provisions of relative heights of groups of features seen in the terrain, and absolute heights of features near the aircraft. In addition, elevation data are useful in increasing the effectiveness of supporting artillery fire.

Position designation often includes the requirement for a graphic record of specific positions of features on the ground. These annotations serve as readily recognizeable cues for mission activities, as well as a method of summarizing intelligence data in a concise manner. Although numerous annotations are provided prior to flight, many must be entered in the aircraft, during performance of the mission.

Present deficiencies. Present procedures for position designation are often awkward and inaccurate. For example, although the military grid reference system permits the location of a point within 10 meters, use of the system to this level of accuracy requires that a coordinate scale, such as that shown in Figure 39, be overlayed on the map. The recipient of these coordinates also must use the coordinate scale in order to plot the designated point on the map. Army aviators have found that the coordinate scale is unsuitable for use in flight, and almost

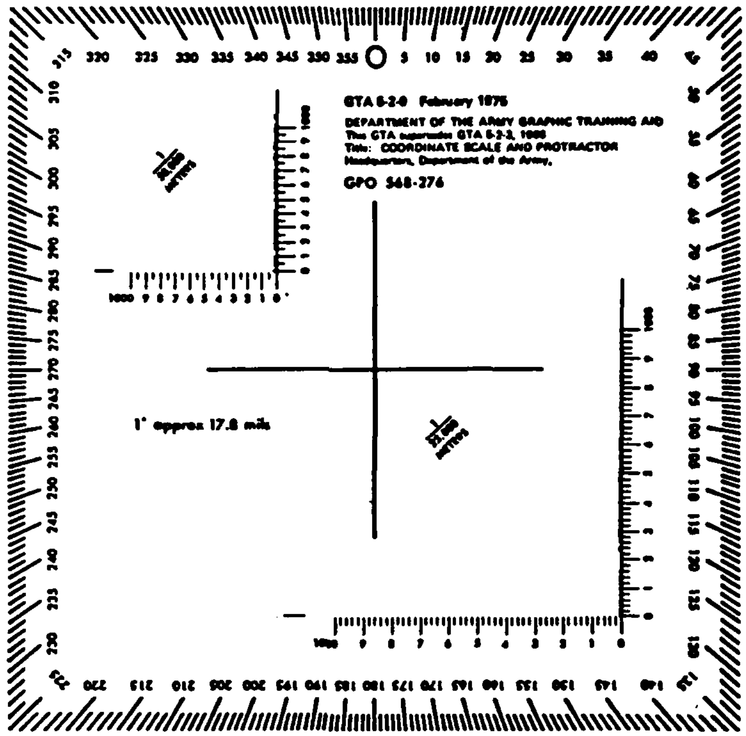


Figure 39. Example of a coordinate scale and protractor.

never attempt to designate positions closer than the nearest 100 meters (six-digit grid coordinates). Even at this level of accuracy, it is commonly acknowledged that errors are made in determining the coordinates, communicating these coordinates, and in applying them to locate a point on the map. Similarly, without the use of a protractor and distance-scaled straight edge, it is difficult to determine or apply range and bearing information to designate positions on a map. Because these devices are also unsuitable for cockpit use, aviators simply make rough estimates of range and bearing--even in such critical applications as target handoffs. The use of the data on 1:50,000-scale topographic maps to convert between grid coordinates and latitude-longitude figures is difficult under any circumstances. In the helicopter cockpit, it is nearly impossible. Determination of elevations at specific positions requires that the aviator count up or down to the nearest index contour line and follow this line to a point where its elevation is given--an awkward and error-prone procedure.

CGTD capabilities. The CGTD computer is capable of speeding point designation, while improving accuracy and precision. Coordinates and elevation of any location on the display may be determined simply by positioning a cursor; or, keying in coordinates will result in a symbol appearing at the designated position. The designation of positions may also be achieved by entering range and bearing data or preselected code names. The CDU also has provisions for annotating the map display, converting UTM coordinates to latitude and longitude, and computing range and bearing of positions from any site on the map display.

CDU operation. When the MENU page is displayed, pressing the line select key labeled POS DES calls the position designation page, as shown in Figure 40. The position designation page provides six options for the specification of positions: by coordinates, by cursor, by range and bearing, by present position, by label, and by latitude and longitude. These options are selected by pressing the line select key beside the labels COORDS, CURSOR, RNG BRG, PRES POS, LABEL, or LAT LONG, respectively. Figure 41 shows the sequence of events initiated by pressing the key labeled COORDS. First, the CDU provides a prompting message to "enter position coordinates" on the keyboard. The CDU will accept keypad entries of four, six, or eight digits. The figure shows that the aviator has keyed in the coordinates 902812. When the ENTER button is pressed, the position data page appears. The position data page displays the grid zone designation (16S) and the 100,000-meter square identification (ES), information that is often required for communication with map users on the ground. Adjacent to these data are the grid coordinates.

Beneath the grid position data, the CDU shows the elevation of the position in meters, and the range and bearing of the position from the present position of the aircraft. These range and bearing data are automatically updated every few seconds. If the aviator has previously entered a reference position (such as a gunship firing position), pressing the line select key labeled FROM REF POS will cause the CDU to display range and bearing from the reference position, instead of from the aircraft's present position. Selection of this mode is indicated by an asterisk adjacent to the FROM REF POS label. Entry of reference positions is discussed later in this section of the report.

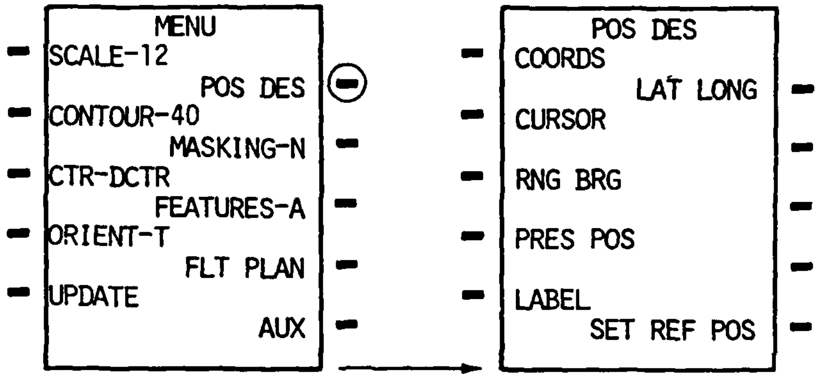


Figure 40. Calling the position designation page on CDU.

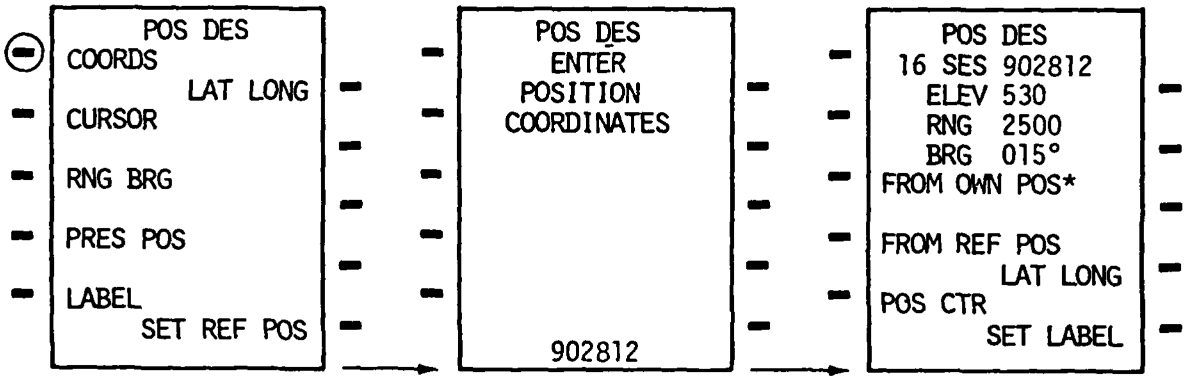


Figure 41. Position designation by entry of coordinates on CDU.

As the above information appears on the CDU, a position designation symbol appears on the map display, as shown in Figure 42. The symbol flashes on and off for three seconds to aid the aviator in identifying the position, and then maintains a steady state. If the symbol is not present in the visible portion of the map display, the PIC may be used to slew the map as indicated by the range and bearing information on the CDU. Another alternative is to press the line select key labeled POS CTR (position center) to bring the selected position to the center of the display. This option functions in the same manner as the destination center feature described earlier in this report.

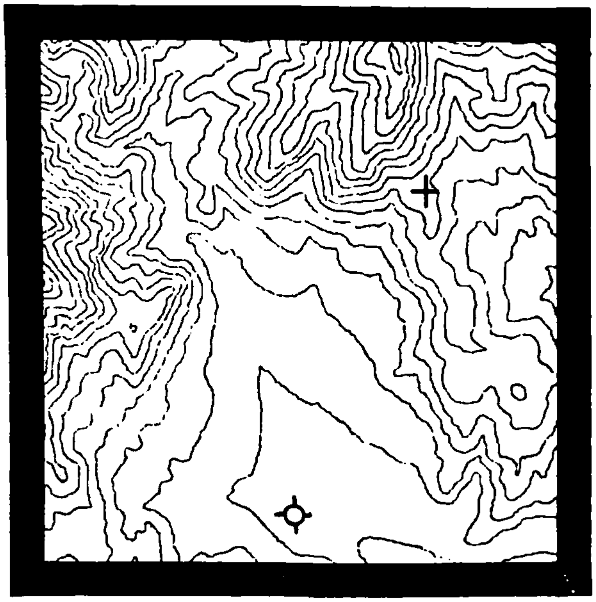


Figure 42. Position designation on the map display.

The second method of position designation is that of entry by cursor, as shown in Figure 43. This method is employed when the position of interest is visible on the map display, but its coordinates are unknown. When the line select key labeled CURSOR is pressed, the CDU provides the prompting message "position cursor and mark," and provides an option to stop map motion (FREEZE) if desired. The aviator uses the PIC to move a cursor from the present position indicator to the position of interest. Pressing the MARK button causes the cursor to stabilize on the designated position, (as in Figure 42) and the position data page to appear on the CDU. In the cases for which more precise coordinates are required, the aviator can press the line select key below the coordinates (labeled "8") to expand the coordinates from six to eight digits. The map resumes motion when the MENU button is pressed.

The third method of position designation is that of range and bearing entry, as shown in Figure 44. This method may be used whenever the transmission of coordinates is undesirable, and may employ any reference position as the origin of the range and bearing data. Pressing the key labeled RNG BRG causes the prompting message "enter range" to appear on the CDU. The system assumes that

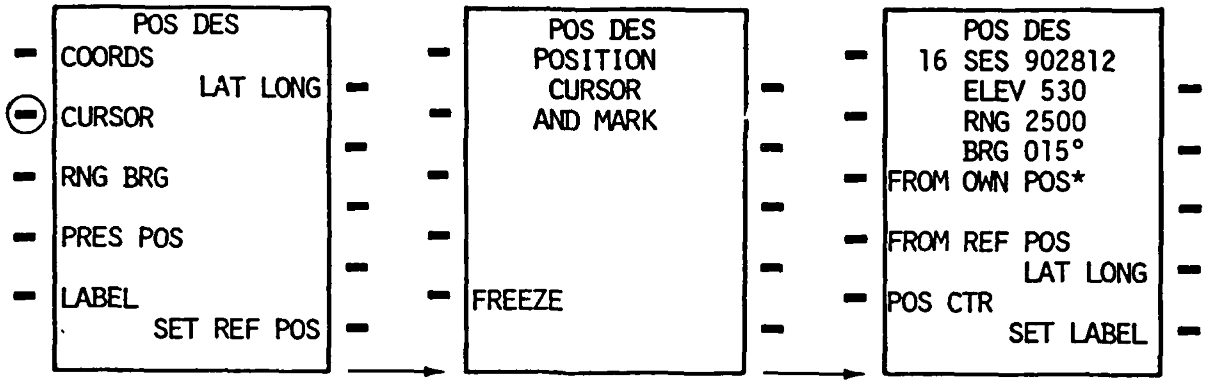


Figure 43. Position designation by cursor.

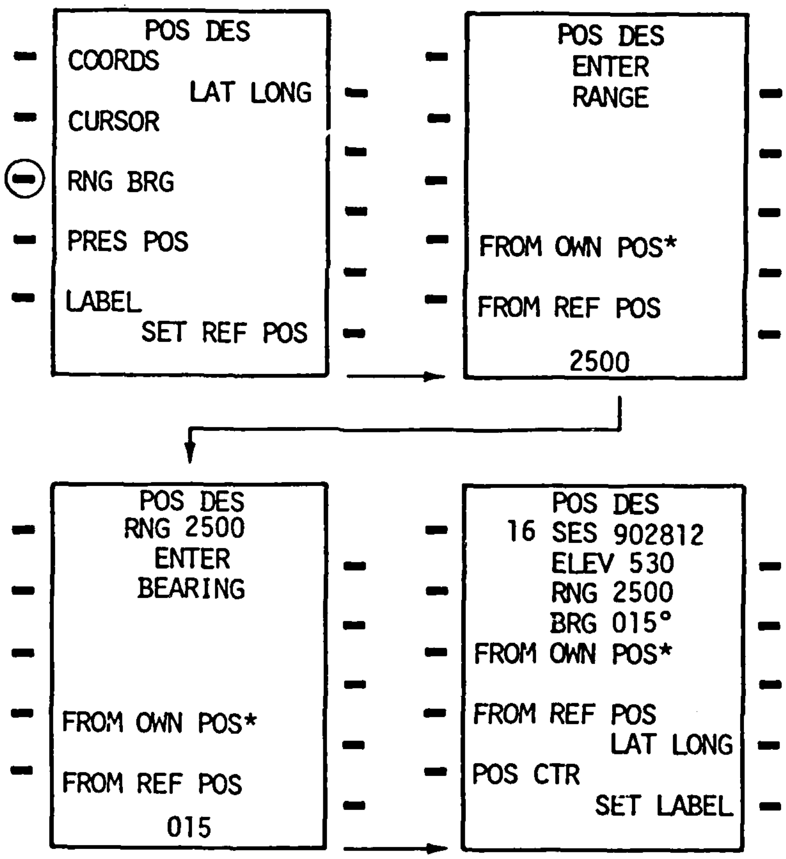


Figure 44. Position designation by range and bearing.

the range and bearing to be entered are from the aircraft's present ("own") position, as indicated by the asterisk adjacent to the FROM OWN POS label. However, should the aviator receive range and bearing information based on another reference position, he may press the key labeled FROM REF POS to enter the data. Entering the reference position is discussed subsequently in this section of the report. Once the range is entered, a prompting message requests entry of the bearing. Upon entry of the bearing, the position data page appears, just as in the previous two methods of position designation.

The fourth method of position designation is that of present position entry, as shown in Figure 45. The only actuation required of the aviator is that of pressing the PRES POS key. The aircraft's present position coordinates and elevation are then displayed on the CDU. The range and bearing data items are inapplicable and are eliminated from the position data page.

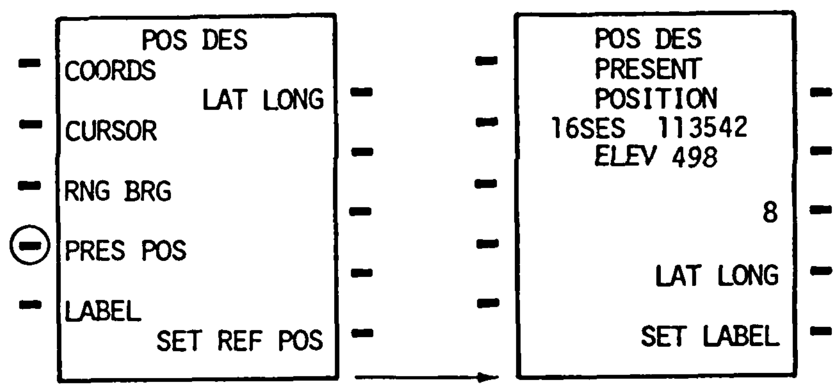


Figure 45. Position designation by entry of present position.

The fifth method of position designation is that of entry by label, as shown in Figure 46. Preselected geographic positions may be identified by an alphanumeric code, such as "A7." Insertion of these coded positions will be discussed subsequently in this section of the report. When the LABEL line select key is pressed, a label entry page is called, as shown in the center of Figure 46. The alphabetic character is selected by pressing the line select key next to the desired letter. On the first press, the leftmost letter is highlighted by a surrounding box.

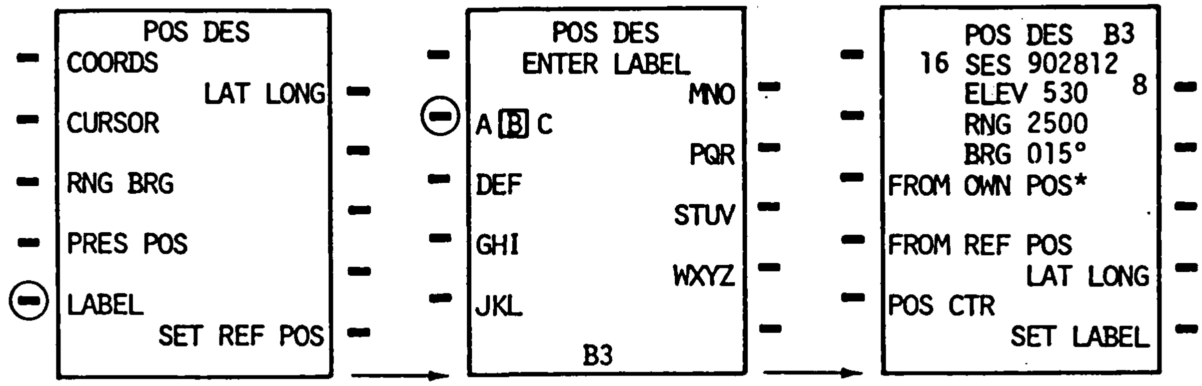


Figure 46. Position designation by labeled point.

On each succeeding press, the next letter to the right is highlighted. The highlighted letter is also displayed in the scratchpad area. The associated number is entered via the keypad. When the ENTER button is pressed, the position data page appears just as in the other modes except that the alphanumeric label is shown beside the page title.

The sixth method of position designation is that of entry by latitude and longitude. The required actuations are shown in Figure 47. When the LAT LONG button is pressed, a prompting message requests the aviator to enter latitude. The north-south selection is made by pressing the appropriate line select key and the degrees, minutes, and seconds (separated by decimal points) are entered by keypad. When the ENTER button is pressed, another prompting message requests the longitude, which is entered in a manner similar to that of latitude entry. Upon pressing the ENTER button, the position data page appears, just as in the previous five modes. Figure 47 also shows the use of the LAT LONG line select key on the position data page--pressing this key converts the UTM grid coordinates to latitude and longitude. Latitude and longitude may be converted back to coordinates by pressing the line select key labeled GRID.

The position data page, in every case except present position mode, shows range and bearing data. This range and bearing may be either from the aircraft's present position or from some other reference position, at the aviator's option. Use of the reference position is particularly useful for target handoffs, where the reference position is the gunship's firing position. The reference position is also

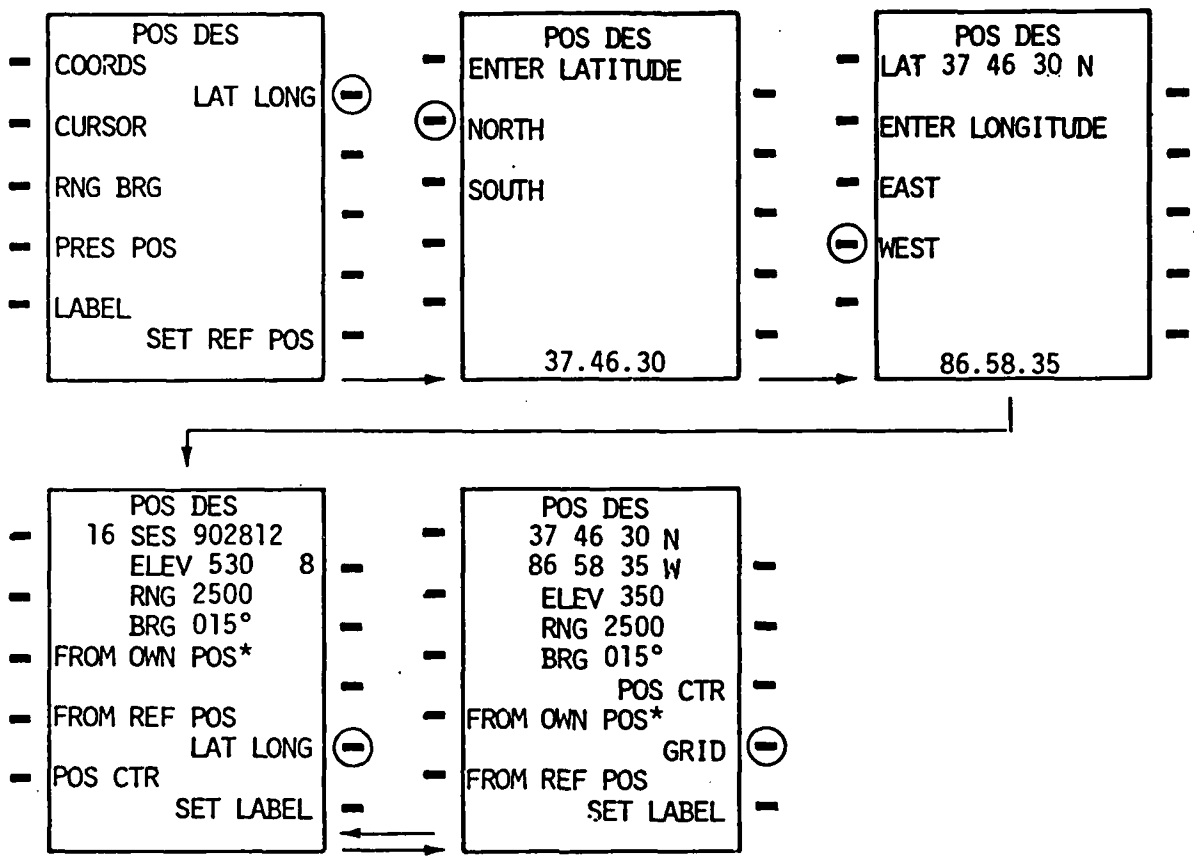


Figure 47. Position designation by latitude and longitude.

valuable for designating positions with reference to preselected checkpoints, objectives, or other features. Entry of the reference position is shown in Figure 48.

Pressing the line select key labeled SET REF POS causes a prompting message to appear, indicating that the aviator may either enter the coordinates of the reference position, or use the PIC to position the cursor over the reference position and press MARK. The coordinates of the previously entered reference position are shown below the prompting message. If new coordinates are set on the keypad, they are shown in the scratchpad area until the ENTER button is pressed, when they replace the previously entered coordinates, and the scratchpad is cleared. Entries by cursor also result in display of new coordinates. The aviator is

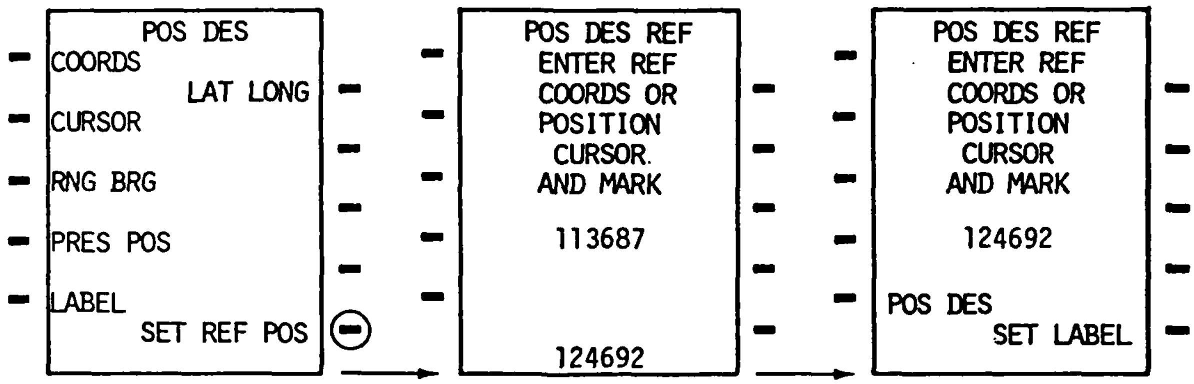


Figure 48. Entry of the position designation reference position.

then provided with three options: he may press the key labeled POS DES to return to the position designation page, press the MENU button for access to any CDU function, or press the SET LABEL key to annotate the map.

Map annotation is often, but not always, desired in the position designation mode. It would sometimes be convenient to have annotations automatically entered at each designated point, but records of every one of these points are not required and could lead to an undesirable level of map clutter, obscuring both terrain data and other more important symbols. On the other hand, some symbol must be introduced to show the location of designated points entered by coordinates, latitude-longitude, or range and bearing methods. In order to satisfy these conflicting demands, temporary symbols are used in the position designation mode, such as simple + signs. These symbols remain on the map display only until the MENU button is pressed. If the aviator desires a "permanent" record of these positions, he must enter a position label as shown in Figure 49. When the SET LABEL key is depressed, a position label page is called. Alphanumeric codes are selected on this page in the same manner as described previously in the discussion of position designation by label entry. When the code is selected and the MARK button pressed, the + symbol defining the position previously designated changes to the selected code, such as "C1." This code is recorded for later reference enroute, or for debriefing. If no further labels are required, the aviator presses the MENU button to prepare for other map functions. It is possible, however, that the aviator may wish to make a series of label entries while the system is in this mode. To

facilitate such a requirement, a + symbol appears at the center of the display after the first label entry. The PIC may be used to slew this symbol to any point on the display. The position label page may then be used, as described above, to enter alphanumeric codes replacing the + symbol. The CLR button, when pressed once, clears the numeric part of the code for a new entry, while leaving the alphabetic letter--thus speeding the entry of a series of codes of the same type (T1, T2, T3, etc.). An example of position labeling is shown in Figure 50. The FREEZE key may be used to stop map motion during this operation, if required. Map motion is resumed when the FREEZE key is pressed again, or when the MENU button is pressed.

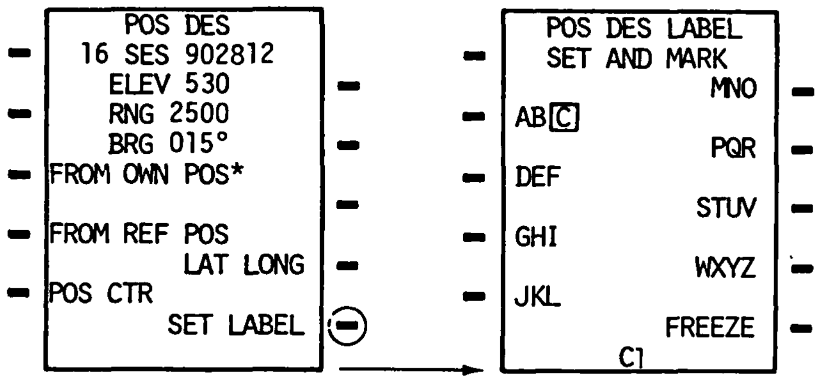


Figure 49. Entry of position designation labels.

Another labeling method is provided for emergency enroute annotations such as those required when receiving fire from an unsuspected enemy position. This method requires only that the MARK button be pressed for a label to appear at the aircraft present position. If the PIC is in a cursor-driving mode, the MENU button must be pressed in order to enable this rapid reaction mode.

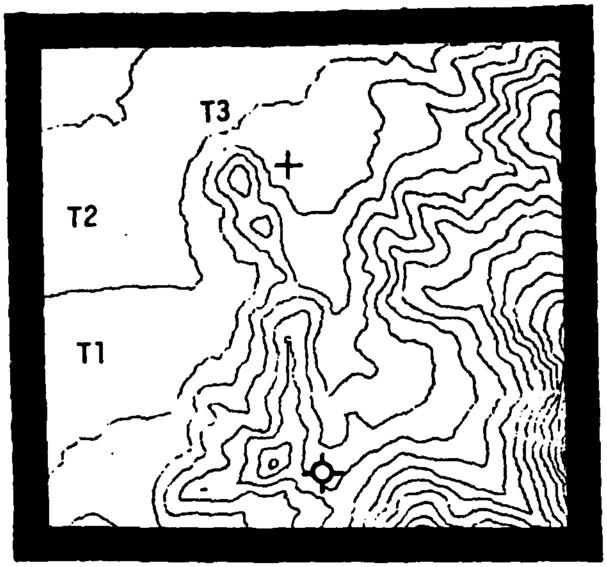


Figure 50. Example of position labeling.

MASKING AND INTERVISIBILITY

Requirements. The term "masking" refers collectively to cover from weapons fire and concealment from visual, optical, or electronic observation. Masking is the central objective of terrain flight, whether of the NOE, contour, or low-level type. It is critical that the aviator be aware of the positions and altitudes at which masking is available. Helicopters exposed to the enemy for more than a few seconds are likely to be destroyed. However, NOE flight should be avoided when it is safe to do so because more sorties can be flown or greater distances covered using contour or low-level flight. In addition, higher altitudes provide a greater margin of safety in dealing with aircraft emergencies and hazard avoidance.

Masking considerations are crucial not only for the selection of flight altitudes and flight routes, but also for planning radio communications; determining enemy and friendly fields of fire; predicting checkpoint visibility; and selecting LZ's, rally points, pickup points, FARRP's, and other tactical sites.

Present deficiencies. Although the importance of masking is clear, no practical methods of accurately determining the masked areas and altitudes from

map study have been devised, except for the most obvious situations and solutions. For example, FM 1-1, Terrain Flying, offers only this advice on planning masked routes:

> To do this in mountainous or rolling terrain, plan the route on the friendly side and below the crest of a ridgeline. In very gently rolling terrain, plan the route across the low terrain such as stream beds where it does not serve as an avenue of approach to the enemy position. In arid or open areas, plan the route along stream beds or depressions where trees may exist.

Examination of standard topographic maps indicates that the masking determinations will often be considerably more complex. The procedure for manually plotting masked areas, based on a series of profiles, is described in FM 21-26, Map Reading. This procedure entails an extremely time-consuming series of steps to plot the masked areas for even a relatively small geographical expanse. Such an approach is totally impractical for an aviator who needs to determine the masking available in broad and long flight corridors, with several known or suspected enemy positions in the area of operations.

CGTD capabilities. A computer-generated topographic display may perhaps make its greatest contribution in the computation of masked areas and altitudes for terrain flight. Such computations are relatively simple ones, but the requirement for hundreds or thousands of computations is the arena in which computers are most valuable and efficient. Through a computer system, masking plots may be produced rapidly. All that is required of the aviator is that he enter the position of the observer or radar site on the display, and indicate the range of plot required (based on atmospheric attenuation, radar return limits, or other tactical considerations). The computer-generated topographic display can quickly produce a plot of the areas visible and not visible to an observer or radar at the designated position.

A number of enemy positions could be designated, if desired, to depict the likelihood of being observed given the actual battlefield situation. It remains only for the aviator to choose the most direct path to his objective through the masked areas, and to select the shortest paths between masked areas when brief exposures are unavoidable. Similar computations may be performed to determine radio

communication points, fields of fire, and the visibility of checkpoints or tactically important sites.

CDU operation. When the MENU page is displayed, pressing the line select key labeled MASKING calls the masking page as shown in Figure 51. The uppermost three keys on the masking page allow the aviator to select a display of masking available in the three different flight modes: NOE, contour, or low-level. The computation of masked areas is done prior to the flight, at the mission-planning console, and is described subsequently in this section of the report. Figure 52 shows examples of masking plots depicted on the map display. The upper portion of the figure shows the areas masked from enemy observation when the aircraft is flown at NOE levels. The lower portion of the figure demonstrates the reduction of the areas masked when the aircraft is flown at a somewhat higher altitude, as in contour flight. An asterisk appears next to the label of the line select key last pressed, and a letter appears next to the page title to indicate the masking display mode. This letter is also present next to the masking label on the MENU page as a reminder to the aviator.

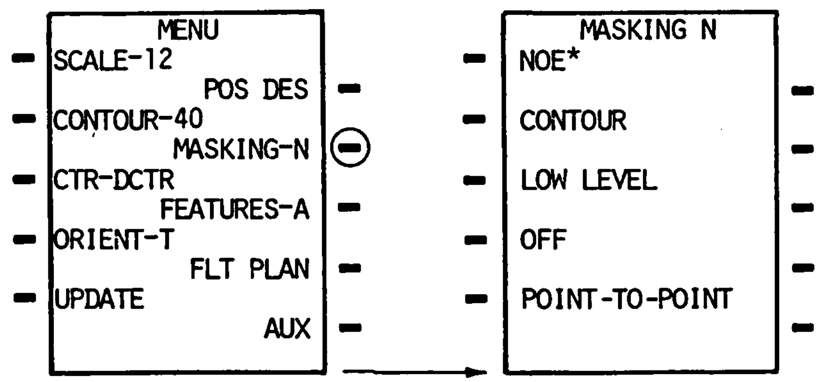


Figure 51. Selection of masking plots for different flight modes by CDU.

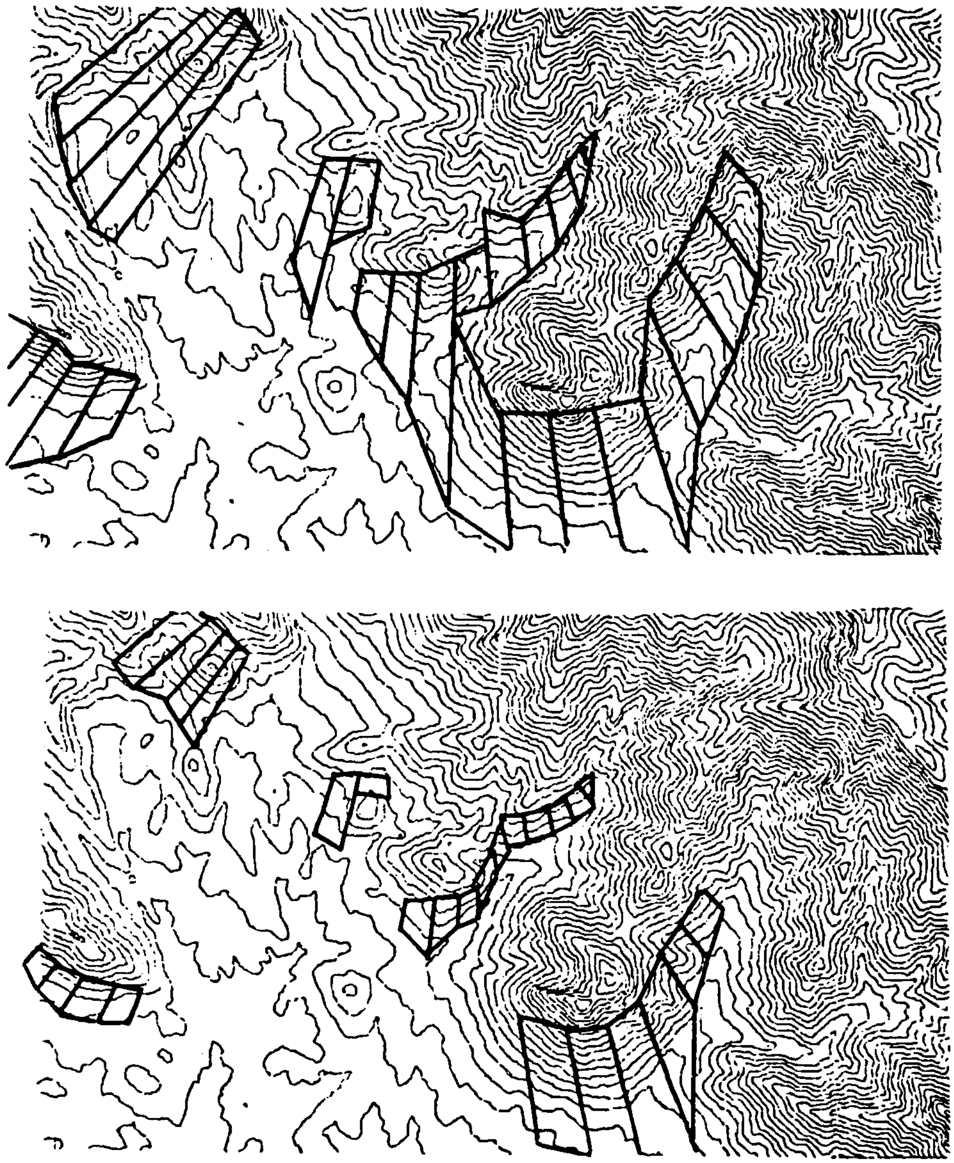


Figure 52. Examples of masking plots at NOE flight level (above), and contour flight level (below).

Although the masked areas are computed by the mission-planning console at the TOC, the aviator is able to compute intervisibility along a straight line while in flight. In order to exercise this capability, he presses the line select key labeled

POINT TO POINT on the masking page. Selection of this option does not affect the NOE, contour, or low-level masking display selected by the other keys on the masking page. Figure 53 shows the sequence of CDU pages presented during the point-to-point masking determination. When the POINT TO POINT key is depressed, the CDU presents a prompting message instructing the aviator to indicate the viewing position (Position 1) by placing a cursor at the desired point on the map display. The PIC is used to move the cursor on the display, and the MARK button is pressed to place a + symbol on the indicated position. Map motion may be halted, if desired, by pressing the key labeled FREEZE. Map motion resumes when

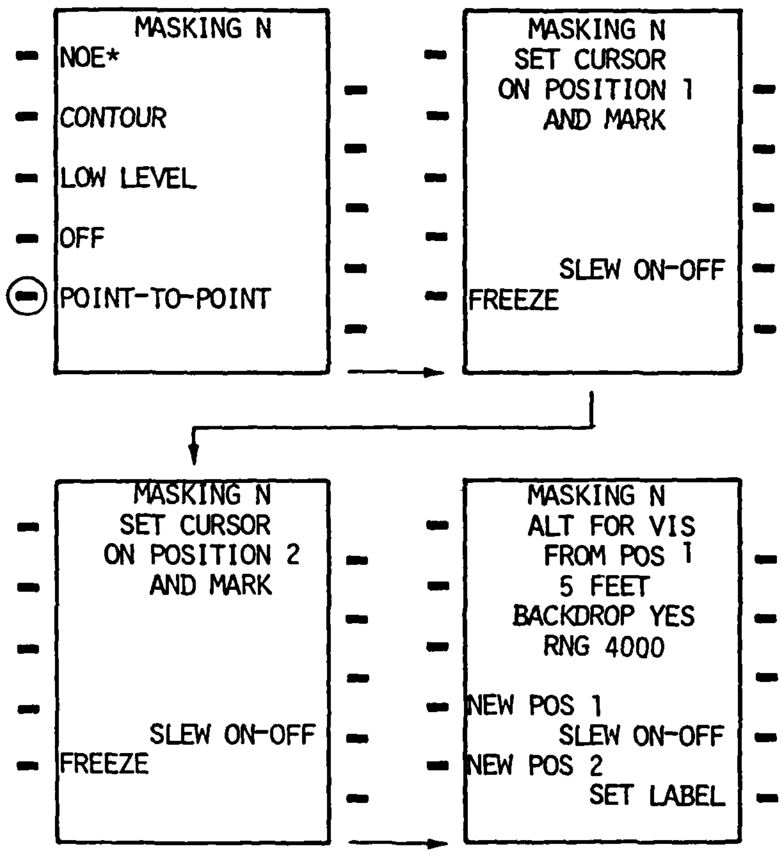


Figure 53. Point-to-point intervisibility computation by CDU.

the MENU button is pressed. The function of the PIC may be alternated between cursor movement and map slewing by pressing the line select key labeled SLEW ON-OFF.

After the Position 1 has been entered, the CDU instructs the aviator to indicate the viewed position (Position 2) in the same manner. When Position 2 has been marked, the masking data page appears on the CDU. This page indicates the altitude above ground level (AGL) at Position 1 required for point-to-point intervisibility. In addition, this page indicates the range between the two positions, and whether or not the aircraft would have a "backdrop" when hovering at the altitude required for intervisibility. The concept of the backdrop is illustrated in Figure 54. The line-of-sight from the tank to the aircraft in this figure is terminated by a landform. Thus, there is a terrain backdrop that greatly increases the difficulty of visually detecting the aircraft. If the aircraft rises to a greater altitude (as shown by the dashed aircraft outline), it would be silhouetted against the sky and would present a relatively easily detectable target to the enemy.

If the aviator wishes to repeat the intervisibility computation with a change to one of the two points, he can do so by pressing one of the keys labeled NEW POS 1 or NEW POS 2 and enter the change with the cursor and MARK button.

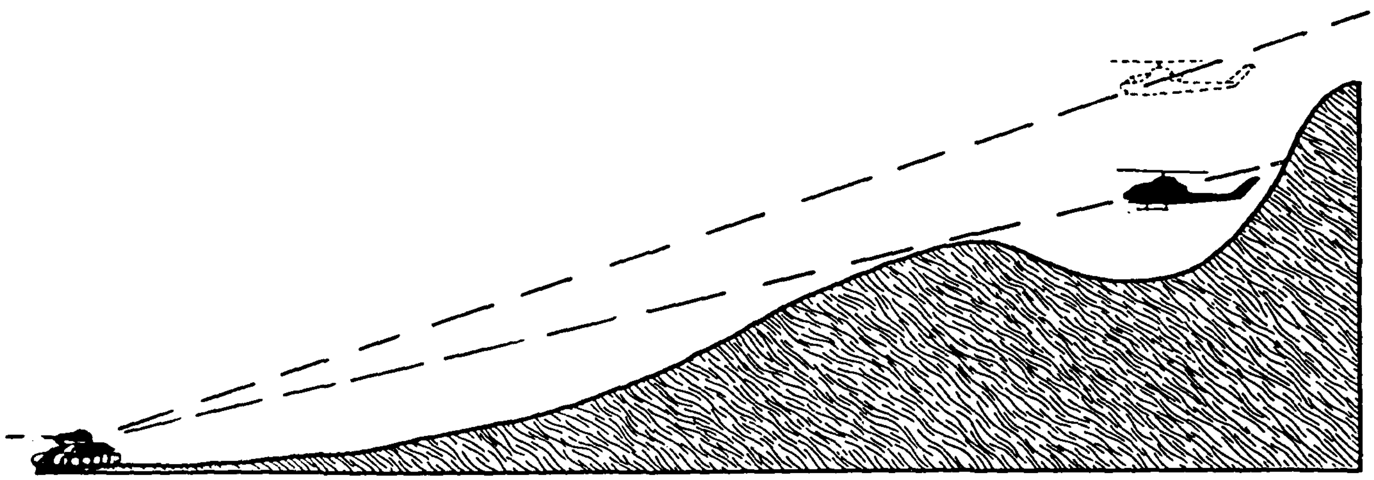


Figure 54. Examples of silhouetting and backdrop.

A graphic treatment of the intervisibility computation is provided on the map display, as shown in Figure 55, by lines extending from Position 1 toward Position 2. The uppermost line in the figure shows that there is intervisibility between Position 1 and Position 2, though not all of the terrain between the two points is visible from ground level at Position 1. The line in the center shows that all of the terrain between the two points is visible from ground level at Position 1. The lower line in the figure shows that Position 2 cannot be seen from Position 1.

The aviator may wish to annotate the map as a result of the point-to-point intervisibility computations. Annotations are entered in a manner similar to that employed in the position designation mode. As shown in Figure 56, pressing the SET LABEL key calls the position label page, and labels may be selected as previously described. When the MARK button is depressed, the selected label will appear at the most recently designated Position 1. Additional labels may be entered by slewing the + symbol with the PIC, and marking as described in the discussion of the position designation mode. If no additional labels are desired, the aviator may return to examination of intervisibility by pressing the POINT TO POINT key, or enter another mode by pressing the MENU button.

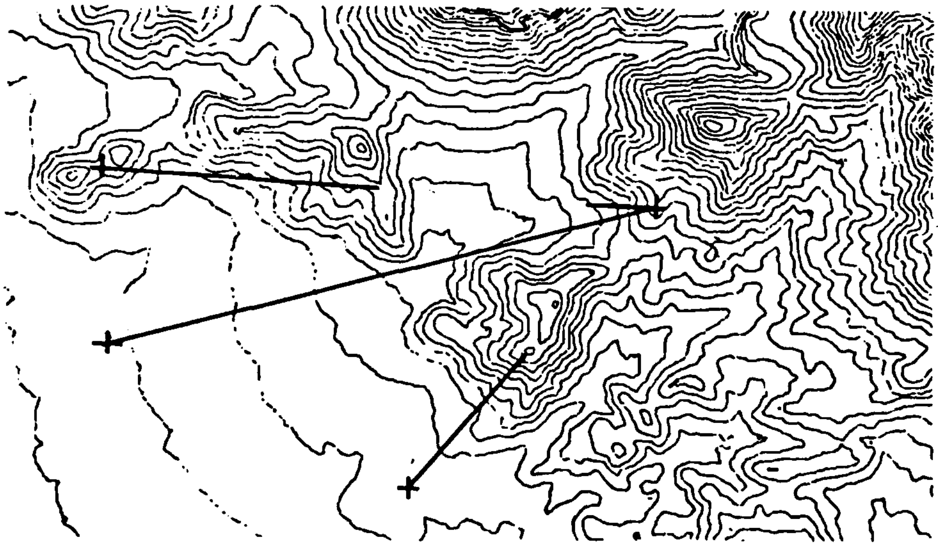


Figure 55. Point-to-point intervisibility representation on the topographic display.

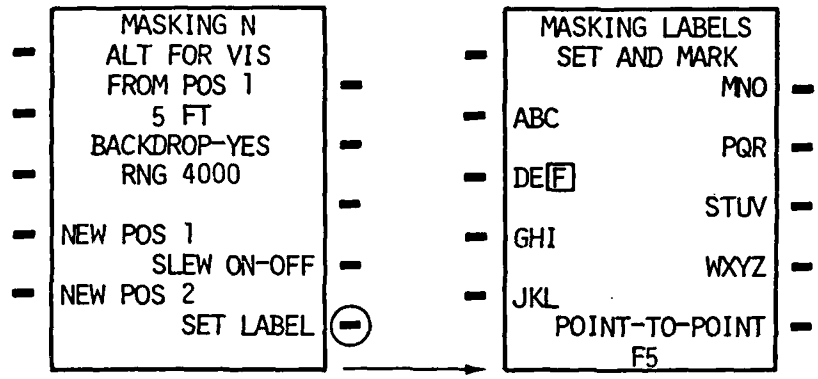


Figure 56. Entry of position labels in the masking mode.

FEATURE SELECTION

Requirements. Because of the many different military activities supported by maps, it is very difficult to make generalizations about the types of features that should be shown on maps. Both the tactical situation and the geographic area determine the importance of various hydrographic, vegetation, and cultural features. If these features could become "key terrain" because of the tactical situation, or are by their nature good navigational checkpoints, they should be portrayed on the map. However, it is not possible to rank hydrographic, vegetation, and cultural features in order of their importance as key terrain or navigational checkpoints without very carefully defining the circumstances. Categories of features valuable in some situations are of little help in others. Although as many potentially useful features as possible should be portrayed, the density of features depicted on the map must not be so great as to create a "clutter" problem, with symbols crowded together, overlapping each other, and obscuring the basic landform contour information.

In order to correlate mission information with the topography in the area of operations, the Army aviator must heavily annotate his map, either directly or with a series of notes and overlays. Dozens of information items are absolutely required, and many more are extremely useful. It is noteworthy that the inability to make these annotations has been a critical shortcoming in the "projected" map display systems. Once again, it is important that the annotations and overlays do not obscure other important features on the map.

AD-A104 388 ANACAPA SCIENCES INC SANTA BARBARA CA F/G 15/7
CONCEPTUAL DESIGN OF A COMPUTER-GENERATED TOPOGRAPHIC DISPLAY S--ETC(U)
JUN 81 S P ROGERS DAHC19-78-C-0012
UNCLASSIFIED 365-81 USAAVRADCOM-TR-78-0012-F NL

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Deficiencies. Because of the high cost of producing paper maps, virtually all products of the Defense Mapping Agency are designed to serve the needs of several different classes of users. It would be impossible to produce maps with all the information desired by all the potential users without cluttering the maps beyond the point of legibility. Consequently, some compromises must be made in each map's information content, so that each class of user is likely to find the map deficient in some manner. Even a map designed specifically for Army aviators could not present all of the potentially useful topographic information because of the clutter problem, and the cartographer is forced to make judgments regarding the items of information best omitted.

Aviators have found that direct annotations must be limited in number if the topographic information is not to be obscured, and that a limited amount of annotations are possible with overlays. Many annotations on a single overlay introduces unacceptable clutter, and attempting to use multiple overlays introduces the problems of positioning errors and lost time in overlay selection and alignment. In addition to the clutter problems, the aviator's attempts to copy tactical information from the situation map at the TOC (or from other aviator's maps) introduces two types of error--errors of inaccurate reproduction of the data, and errors of omission of critical items of information because their value is not immediately apparent.

CGTD capability. The CGTD permits the aviator to select any combination of topographic features and tactical information so that he may design an optimal map display for mission-planning and in-flight use, no matter what type of terrain or battlefield situation he encounters. Various overlays and annotations may be displayed at will or rapidly deleted to study the underlying topographic data. Because the aviator controls the feature selection rules, he is also in control of the density of displayed information and can prevent or eliminate disruptive clutter.

The battlefield situation data produced by the G2/S2 and G3/S3 is entered on the map cassette from a master tape at the TOC, so that the aviator is provided with the most recent data--and the time losses and errors accompanying manual reproduction of situation map data are eliminated. In addition, the problems of

overlay selection, positioning, alignment, and smearing are avoided. Furthermore, the aviator may annotate the cassette with planned course lines, checkpoints, and other data, either at the mission-planning console or in the aircraft, and display this information at will. The CGTD is also capable of providing the aviator with auxiliary descriptive data when needed, and otherwise limit alphanumeric information on the display. Just as grid coordinates and terrain elevations are available on demand, it is possible to query the system regarding other known characteristics of features, such as tree heights or stream depths.

In summary, the CGTD permits the aviator to tailor the feature selection rules to best suit his needs depending upon the type of terrain and the level of clutter acceptable on the display screen. This tailoring might take the form of selecting or eliminating an entire class of features. For example, all cultural features might be displayed in an area where their reliability is good, and no vegetation codes would be depicted where the vegetation paterns in the terrain are indiscriminable. More complex feature selection rules could be involved. The aviator can control the selection of specific features within a given class, such as displaying only the perennial drainage features and eliminating the intermittent streams. Like scale and contour interval selectability, feature selectability would permit the aviator to maximize the accuracy and utility of the topographic portrayal while minimizing the presence of irrelevant information and clutter on the display.

CDU operation. When the MENU page is displayed, pressing the line select key labeled FEATURES calls the feature selection page as shown in Figure 57. The aviator can use the line select keys on this page to define the combination of topographic and tactical data displayed. Pressing the ALL key causes all available topographic and military data to be displayed, regardless of the clutter this may produce. The TOPO key is used when the aviator wishes to view only topographic data. The FLT & TOPO key is used when the aviator wishes to view his preflight annotations overlaid on the topographic data. The PP ARTY key is used to display preplanned artillery fire data superimposed on the topographic data. In addition to these four options, three PRESET Keys are provided. The PRESET keys are used to call up various combinations of topographic and military features determined to be

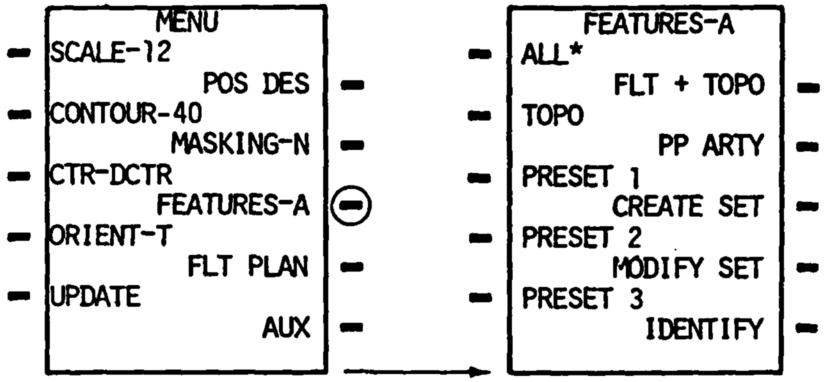

Figure 57. Calling the feature selection page on CDU.

useful in a given geographic area or tactical situation. An asterisk appears beside the selected label, and a letter indicating the selection appears at the top of the page, and beside the FEATURES label on the MENU page. Thus, a total of seven combinations of features may be selected by a key press. Furthermore, the specific contents of each of these seven differs depending upon the map scale selected, so that as many as 28 different combinations of features may be selected.

Creating these feature sets is initiated by pressing the line select key labeled CREATE SET. This and the subsequent CDU operations are shown in Figure 58. Pressing the CREATE SET key calls Page 2, which requests the aviator to indicate whether he desires all, none, or part of the topographic and military information available. By successive depressions of the adjacent line select keys, the aviator can move the highlighting box to the appropriate words. If he requests all or none of a feature class, no further queries are made by the system regarding that class. In the example in Figure 58, the aviator has indicated that he desires part of the information available from each of these two basic categories. Pressing the CONTINUE key calls Page 3, which requests the aviator to indicate whether he wants all, none, or part of the three basic categories of topographic features. In this example, the aviator has selected part of the cultural features, so pressing the CONTINUE key calls Page 4, a request for specification of the portion of cultural features desired. The aviator presses the line select key adjacent to the desired feature labels, using the PAGE key if necessary to view all of the available feature types. When all of the desired features have been selected, the CONTINUE

key is pressed. In the example, the system has queried the aviator regarding the military features desired (Page 5) and he has indicated that part of the friendly situation and all of the enemy situation, flight data, and other information is desired. Pressing the CONTINUE key calls Page 6, where the friendly situation features are selected, in a manner similar to that used in selecting the cultural features. When the system has led the aviator completely through the feature selection process in accordance with his requests, the feature storage page (Page 7) appears. The feature storage page performs two functions. First, it provides a record of previous storage entries in a matrix format. In the example, the diagonal marks show that feature sets have been entered in Preset 1 of each map scale, and Preset 2 of the 12K map scale. The second function of this page is to provide a method for feature set storage. Pressing the line select keys labeled with the map scales causes a marker to appear in the associated Preset 1 position. Subsequent key presses move the marker to the adjacent positions. In the example, the marker has been positioned to indicate that the feature set should be stored in Preset 2 of the 12K map scale. Pressing the STORE key enters the feature set in the memory so indicated. The same feature set may be entered in other preset memories, as desired.

Another method of feature set compilation is provided to introduce modifications to the feature set in use. This method is initiated by pressing the MODIFY SET Key, as shown in Figure 59. Employment of this method requires that the aviator be provided a card with a list of available features and a code number for each feature. As instructed by the CDU, the aviator enters the selected feature code on the keypad and indicates by line select key whether the features is to be added to or deleted from the feature set currently displayed. The selected features flash on and off briefly before disappearing or upon appearing on the map display. The aviator may continue to add and delete features as long as this mode is enabled. The modifications thus introduced will remain on the map display until some other scale or feature group is selected. If desired, the modified feature set may be entered into the memory of any preset via the feature storage page, called by pressing the STORE key.

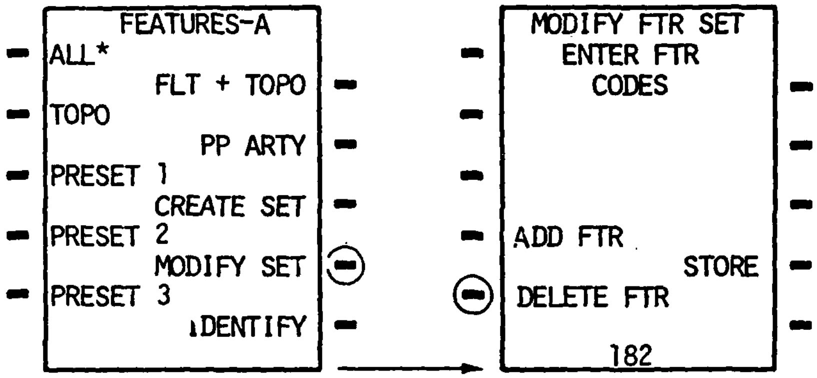

Figure 59. Modification of a feature set.

It is possible that digital terrain data bases will soon become extremely rich in content, so that more information will be available than can be simultaneously displayed. Such data bases are already in existence for limited geographic areas. When such rich data are available, the CDU can be used to interrogate the system regarding the characteristics of terrain features by pressing the IDENTIFY key, as shown in Figure 60. The CDU instructs the aviator to position the cursor and press the MARK button to indicate the feature for which additional information is desired. In the example, the system has shown a vegetated area to be a stand of deciduous trees averaging 10 meters in height. The SLEW ON-OFF key may be used to alternate between moving the map and moving the cursor with the PIC.

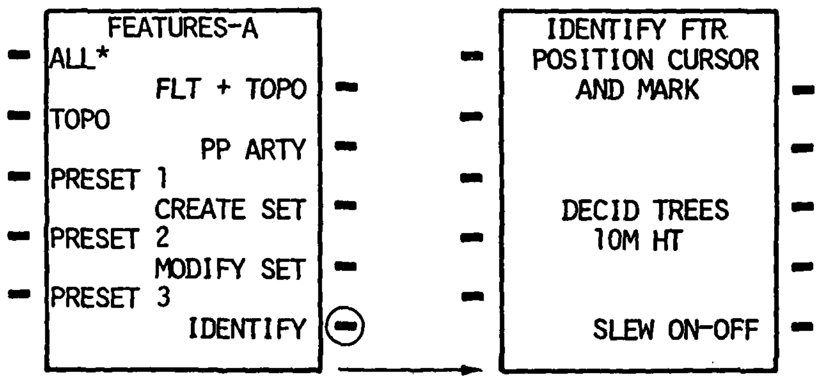

Figure 60. Interrogating the data base regarding terrain feature characteristics by CDU.

FLIGHT PLAN

Requirements. After mission-planning tasks have been completed, the aviator must annotate his map with data to indicate the selected flight path to and from the objective and, in some cases, alternate routes to be used in the event of changes in the battlefield situation. The aviator normally annotates the map with air control points (ACP's) coincident with easily recognized terrain features. ACP's have the dual role of checkpoints and cues for some tasks, such as turning to a new general heading, communicating by radio, or changing from contour to NOE flight mode. Lines are drawn between the ACP's to define the legs of the flight, even though the actual flight path is a weaving one. The length of the legs is measured and the headings are determined by protractor (plotter). The length and heading data may be recorded on the map sheet or in some type of log or kneeboard.

When enroute, the ACP's and course line annotations are used to maintain the appropriate courses and airspeeds for successful performance of the mission. Frequent checks are made to determine the present position of the aircraft with reference to the ACP's, and to determine required changes in aircraft course and speed in order to arrive at ACP's or the objective on time. Timely arrival is particularly critical in crossing friendly lines at scheduled air passage points (to avoid friendly air defense artillery), in following a supporting artillery curtain along the flight route, and in massing for a surprise attack on enemy positions.

Present deficiencies. Although paper maps are easily annotated, penciled-in lines tend to obscure topographic data, grease pencil annotations often smear, and acetate overlays may be difficult to keep in position. Measurement of the course line lengths and headings is somewhat clumsy, especially when contingency operations require that these tasks be performed in flight. Determination of the appropriate headings and airspeeds for timely arrival at ACP's is inexact and inconvenient.

CGTD capabilities. When it is possible for the aviator to report to the TOC for a pre-mission briefing, he will be able to use the special features of the IMPS system to perform mission-planning tasks. It is not unusual, however, for the

aviator to receive fragmentary orders by radio. For this reason, the airborne CGTD permits certain annotations to be made in the aircraft, including the entry of ACP's and the planned flight path. In flight, the CGTD can provide the range and bearing of these ACP's on demand. In addition, the CGTD can compute the time required to arrive at an ACP at current speed, or the speed required to arrive at a given time.

CDU operation. When the MENU page is displayed, pressing the line select key labeled FLT PLAN calls the flight plan page as shown in Figure 61. This page displays the number of the upcoming ACP, its range and bearing from the aircraft's present position, and the time required for arrival at the ACP given straight-line flight at the current speed. Because the aircraft will seldom fly in a straight line, the aviator will have to increase this time by some factor to account for the time increment resulting from his flight mode and the terrain type. In some cases, however, meeting the arrival time requirements may be so critical as to necessitate flying in a path approximating a straight line. The required speed for this "dash" mode is displayed on the CDU when the aviator presses the RQD SPEED key and enters the time remaining before arrival at the ACP, as shown in Figure 62. When the ACP is reached, the aviator enters the subsequent ACP, as shown in Figure 63. The system could be programmed to simply step to the next ACP upon pressing this key, but an aviator entry permits the use of ACP's in any order--such as in reverse order for the return flight.

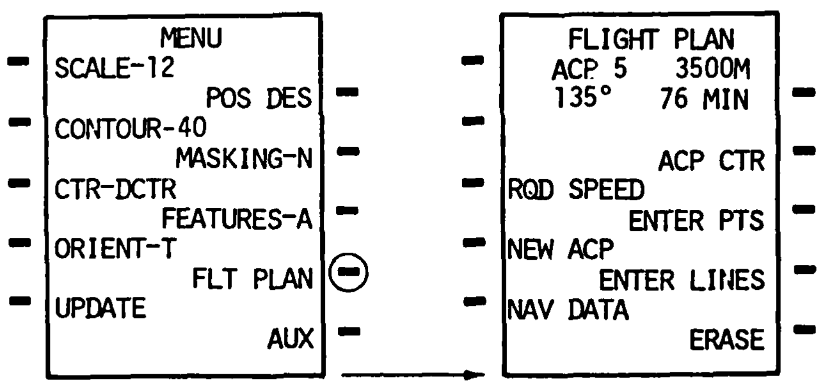

Figure 61. Calling the flight plan page on CDU.

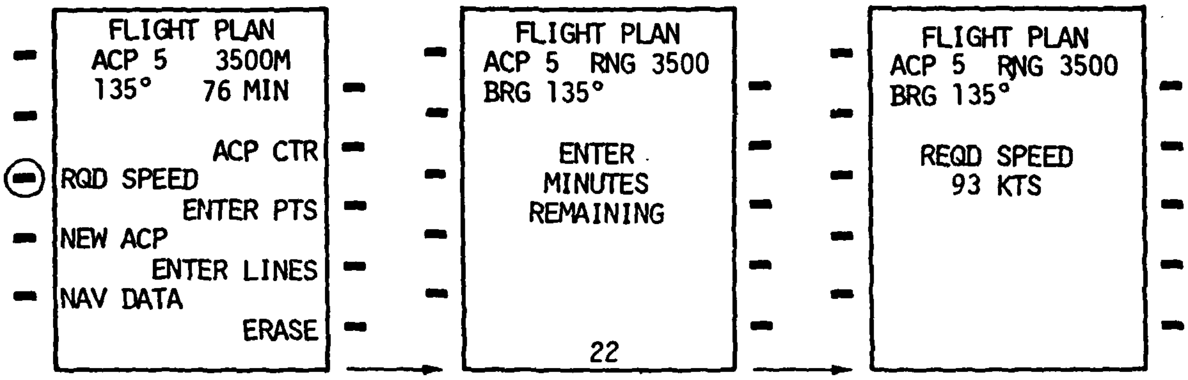

Figure 62. Display of required speed for on-time arrival at an ACP.

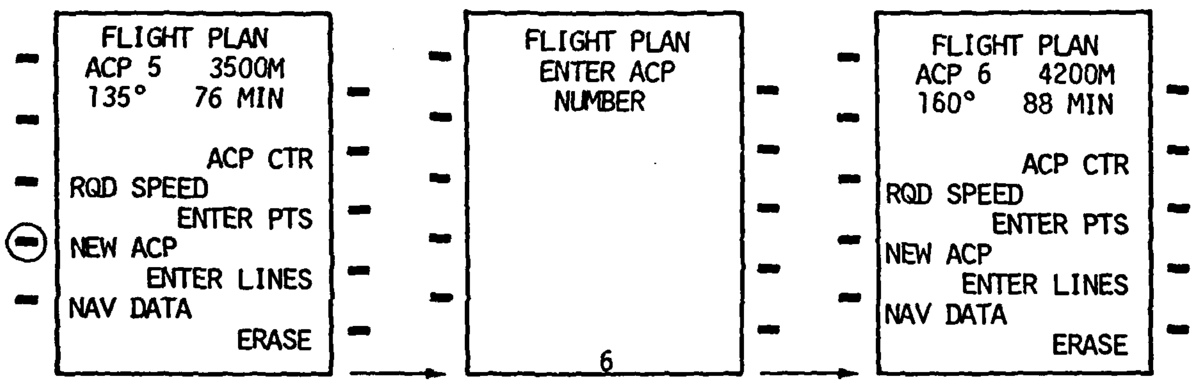

Figure 63. Entering the upcoming ACP on CDU.

The line select key labeled NAV DATA calls a page providing miscellaneous data, as shown by the example in Figure 64. This page might be used to present magnetic declination, spheroid and grid designations, and wind data computed by the navigation system.

The definition of the navigation system, its inputs to the CGTD, and its navigation data to be displayed are not within the scope of this report, which is intended to discuss topographic and tactical data displays. Nevertheless, it may be useful to restate some previous observations regarding steering information and wind data. Although it would be possible to incorporate a track pointer showing the present velocity vector and a command-course indicator showing the heading to a programmed destination or waypoint directly into the map display, such features

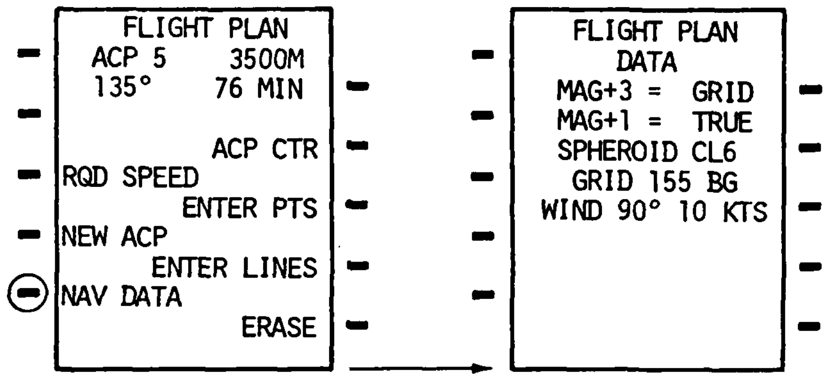

Figure 64. Display of miscellaneous navigation data.

may not necessarily be advantageous. A survey of fixed-wing aviators, for example (Carel et al., 1974) showed that they preferred to use conventional cockpit instruments for steering information, and use the (projected) map display mainly for orientation information.

Airspeed sensing with a conventional pitot static probe is very inaccurate at low speeds. Furthermore, the wind vector is extremely variable at NOE altitudes. Army aviators have reported (McGrath, 1976) that a five-knot vector error is to be expected in NOE flight. Thus, the utility of displaying wind data for NOE flight is somewhat doubtful, although it would serve a purpose for conventional flight.

The ACP CTR key is used in a similar manner to the position center and destination center functions described in previous sections of this report. Pressing this key causes the designated ACP to appear at the center of the map display, and map motion is halted. The aircraft present position indicator moves toward an ACP symbol in accordance with the motion of the aircraft over the terrain. The map resumes its prior centered or decentered mode when the ACP CTR button is pressed again, or when AC CTR or AC DCTR keys are pressed in the CTR-DCTR mode.

Entry of the ACP's and other data points is initiated by pressing the line select key labeled ENTER PTS, as shown in Figure 65. The alphabet letter selection is performed in the same manner as described in previous sections. The letter A, however, is understood by the system to stand for ACP. When the ENTER

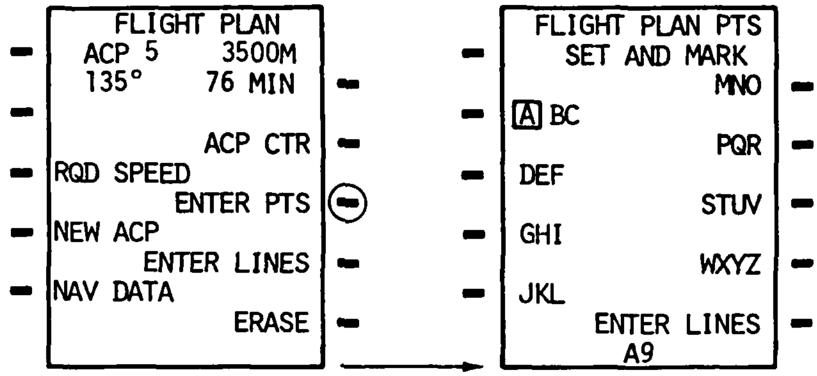

Figure 65. Entry of ACP's and other data points.

PTS key is pressed, a cursor appears at the center of the map display, the PIC is used to slew the map, and positions are designated by bringing them under the cursor and pressing the MARK button.

The method of drawing the lines between ACP's (or other types of lines) is shown in Figure 66. The ENTER LINES key is pressed, the beginning point of a line is positioned under the centered cursor, and the MARK button pressed. The map is then slewed to bring the first turning point under the cursor, and the MARK button is pressed again, causing a line to be drawn between the two points. The length of the line between each two points is shown in the CDU. The slew and mark operation is continued until the last point, where the aviator presses the key labeled STOP LINE, and the MARK button. The line is concluded at this point, and the length of the entire line is displayed on the CDU. The virtue of this method is that it permits the aviator control over the complexity of the displayed route. He may use many turn points to approximate the actual flight path, or a few simply to connect the ACP's. It would be feasible to program the system to connect the ACP's automatically and eliminate the need for this pilot task. Implementation of this option, however, would depend upon the capability of the system to provide enough ACP's to permit route-drawing to satisfactory levels of complexity.

Erasure of points and lines is possible by pressing the ERASE key and using the PIC and mark key in the same manner as for data entry, as shown in Figure 67. Examples of point entry and line entry are shown in Figure 68.

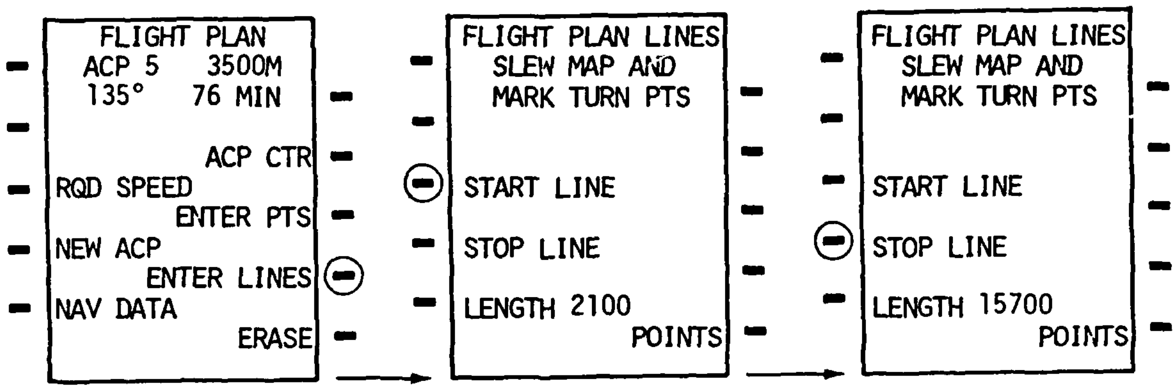

Figure 66. Entry of lines by the CDU and PIC.

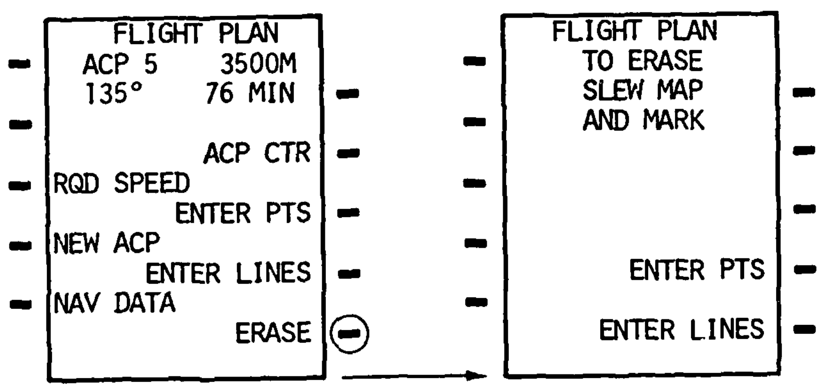

Figure 67. Initiation of the erase procedure.

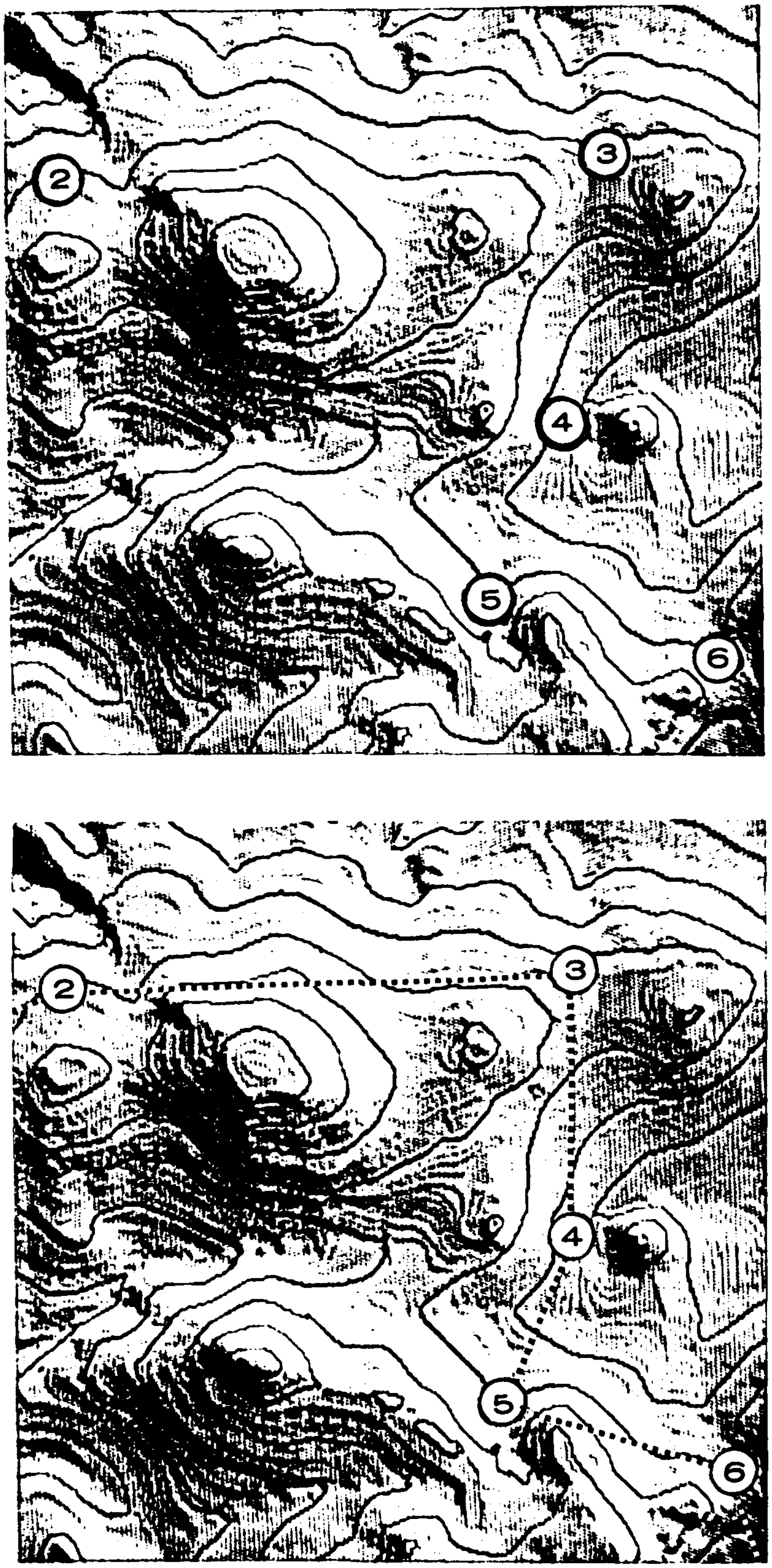

Figure 68. Examples of flight plan point and line entry.

OPERATION OF MISSION-PLANNING SYSTEM

This subsection of the report describes the procedures employed in operation of the IMPS system. The IMPS system provides all of the functions performed by the airaborne CGTD (with the exception of aircraft position updating). In addition, the IMPS provides three sets of special functions important for mission planning. The requirements for each set of functions, and the present deficiencies in providing these functions are briefly described, followed by short discussions of the capabilities of the IMPS system for meeting the requirements and overcoming the deficiencies. The MENU page for the IMPS CDU is shown in Figure 69. The IMPS MENU page provides the same line labels as the airborne CGTD for all but the lowermost two line select keys. The general procedures for use of the CDU are also similar to those for the airborne module. In the subsequent paragraphs, operational procedures are described for the following three sets of special IMPS functions:

Editing
Flight Planning
Oblique View Construction

EDITING

Requirements. One of the central activities at tactical operations centers is the maintenance of well-edited situation boards and associated special overlays showing such data as enemy disposition, friendly disposition, fuel and armament locations, hazards and obstacles, battle positions, assembly areas, radar coverage charts, artillery target points, and the scheme of maneuver for operations. Some of these data are from combat information--raw data used for fire and maneuver as received, without interpretation or integration with other data. Another portion of these data are intelligence--data that have been analyzed, validated, or integrated with other data. Much of the information is operations data, either locally generated, or received from superior or supported units.

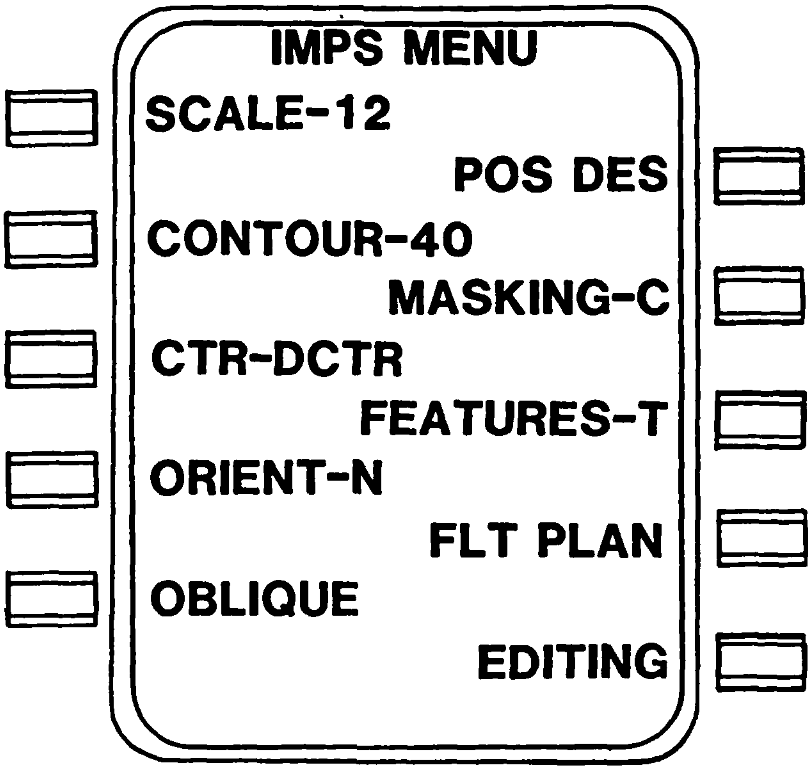

Figure 69. The MENU page of the CDU used in the IMPS system.

Any of these types of information may be critical to successful military operations, and must be supplied to aviators in accordance with their requirements for specific mission data.

Present deficiencies. The primary deficiency in dealing with combat information, intelligence, and operations data is in conveying the critical information to those who need it most--aviators who must perform combat missions. The TOC typically has far more information than the aviator can use for a given mission and selecting just the important information items is a time-consuming task, whether it is performed by TOC personnel or the individual aviators. The situation board overlays are too large and often too cluttered for in-flight use. When portions of these data are copied for specific missions, however, two types of errors are introduced: errors of inaccurate data reproduction, and errors of omission of critical data. In addition, as previously discussed, overlay use presents

problems in the aircraft, especially if multiple overlays are required for presentation of all of the useful information.

IMPS capabilities. The IMPS system permits the storage and selective display of many types of digital "overlays." These data bases may be updated rapidly by several types of entry devices. A keyboard, keypad, light pen, or joystick and cursor may be used to enter and erase features in the various data bases. A special capability for map overlay digitization is also perovided. As previously described, the IMPS has the additional capability of computing masking for terrain flight route selection, and fields-of-fire determinations.

Any of the data base "overlays" generated by the IMPS can be selected or deleted in the cockpit by pressing line select keys. Thus, the problems of handling multiple acetate overlays and obscuration of topographic data during flight are eliminated. Furthermore, the IMPS editing capability significantly increases the likelihood that aviators will be provided with the most current, accurate, and complete information available.

CDU operation. When the IMPS MENU page is displayed, pressing the line select key labeled EDITING calls the editing page, as shown in Figure 70. This page may be used to initiate overlay entry, to plot masking diagrams, to enter or erase tactical features, and to test the map display.

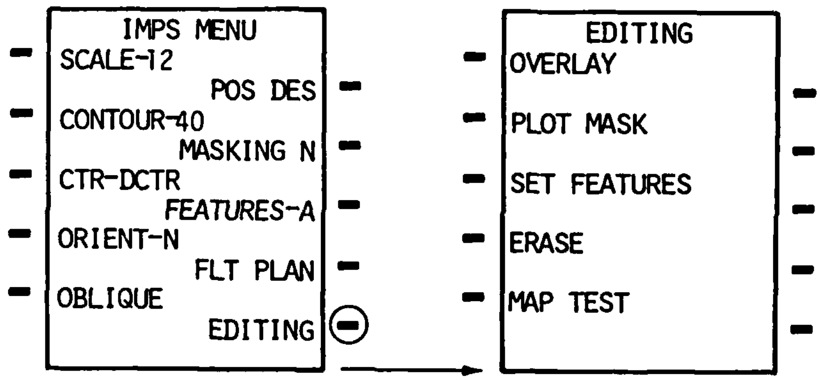

Figure 70. Display of the editing page.

Overlay entry. The use of the system to enter an overlay is shown in Figure 71. When the OVERLAY key is pressed, the CDU provides the operator with a choice of map scales (page 2) corresponding to typical paper map scales. The line select key labeled OTHER will permit the designation of unusual scales, should they be required. Once the map scale is set, the CDU calls for a description of the type of overlay data to be entered (page 3), such as friendly situation, enemy situation, obstacles, and so forth. This description serves two purposes. First, it permits the aviator to subsequently select these individual categories of information, either during mission planning or in flight. Second, this description automatically determines the overlay color. Should an overlay be received with all types of information intermingled, the operator may simply use the ALL key, or, if time is available, he may mask off parts of the overlay to digitize different types of data separately.

Next, the operator must scribe grid register marks on the overlay (as shown in Figure 72) and provide the coordinates of these marks to the IMPS system by keypad, as shown in pages 4 and 5 of Figure 71. The system then (page 6) instructs the operator to place the overlay on the digitizing table in a north-up orientation. When the operator indicates that the overlay is ready for digitizing, the CDU shows that digitizing is underway (page 7) or completed (page 8). This final page presents the operator with several options. He may enter additional overlays of the same type and scale with different grid register marks by pressing the NEW COORDS key, which calls pages 4, 5, and 6. He may enter overlays showing a different type of information (but use the same scale and grid register marks) by pressing the NEW TYPE key, which calls page 3, followed by page 6. The NEW SCALE key, in similar fashion, calls page 2 followed by page 6. If two, or all of these factors are to be changed, the NEW OVERLAY key can be used to call page 2 and all subsequent pages. When the overlay data are entered to the operator's satisfaction, the STORE key may be used to record the data semi-permanently on the master tape.

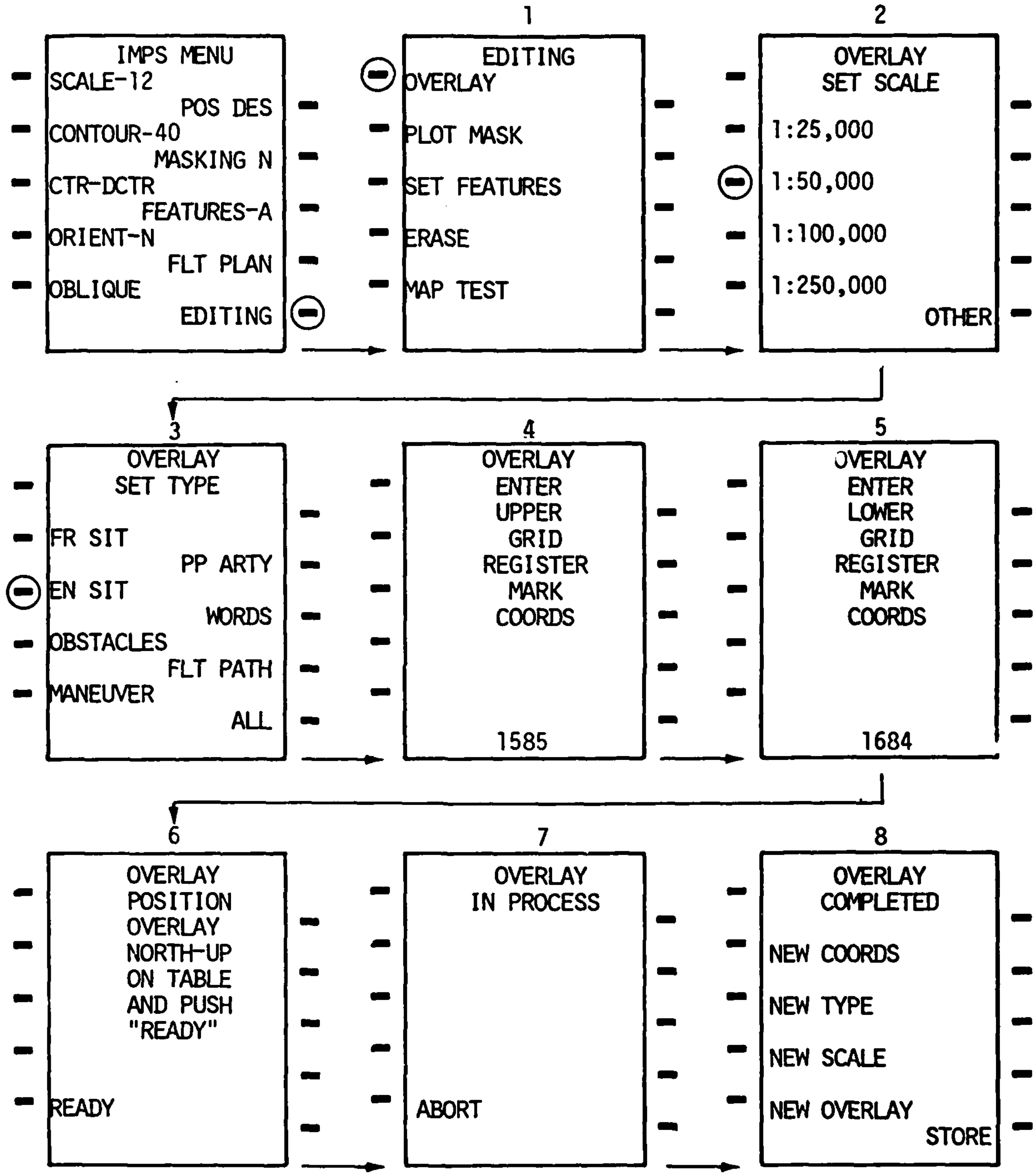

Figure 71. Steps in the entry of overlay data.

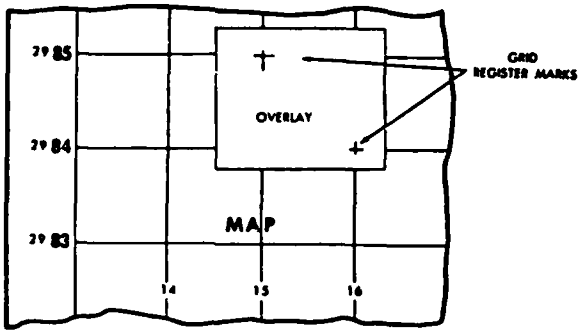

Figure 72. Annotating the overlay with grid register marks.

Plotting masking diagrams. The operator initiates the plotting of masking diagrams by pressing the PLOT MASK key on the editing page. The subsequent sequence of pages is shown in Figure 73. First, the CDU requests the operator to indicate the average tree height in the area. In areas where vegetation coding is current and the trees provide effective masking, this entry will be extremely useful in identifying masked sites and routes. Otherwise, the operator may simply enter "0" to continue. Pages 3, 4, and 5 request data on the enemy sensor/weapon--its position, effective range, and the field of view of concern. The position may be entered by coordinates, by the joystick and cursor, or by the light pen. The range is always entered by keypad. The field of view may be entered two azimuths from the position (by keypad), or by marking the two outer edges of the field with the cursor or light pen. Although a 360-degree field may sometimes be desired, reducing the field will speed the computations. Page 6 permits the operator to enter data on additional enemy positions by presenting pages 3, 4, and 5 as many times as required. When no additional positions are to be entered, the operator indicates the flight altitude above ground level for which the masked areas are to be plotted. Depending upon the terrain type and unit SOP, different altitudes will be designated as corresponding to NOE, contour, and low-level flight. Page 8 indicates that the plot computations are in progress, and provides an ABORT key in case the CDU is urgently required for other purposes. When the computations have been completed, page 9 appears on the CDU, permitting the operator to store the completed plot as an NOE, contour, or low-level masking diagram.

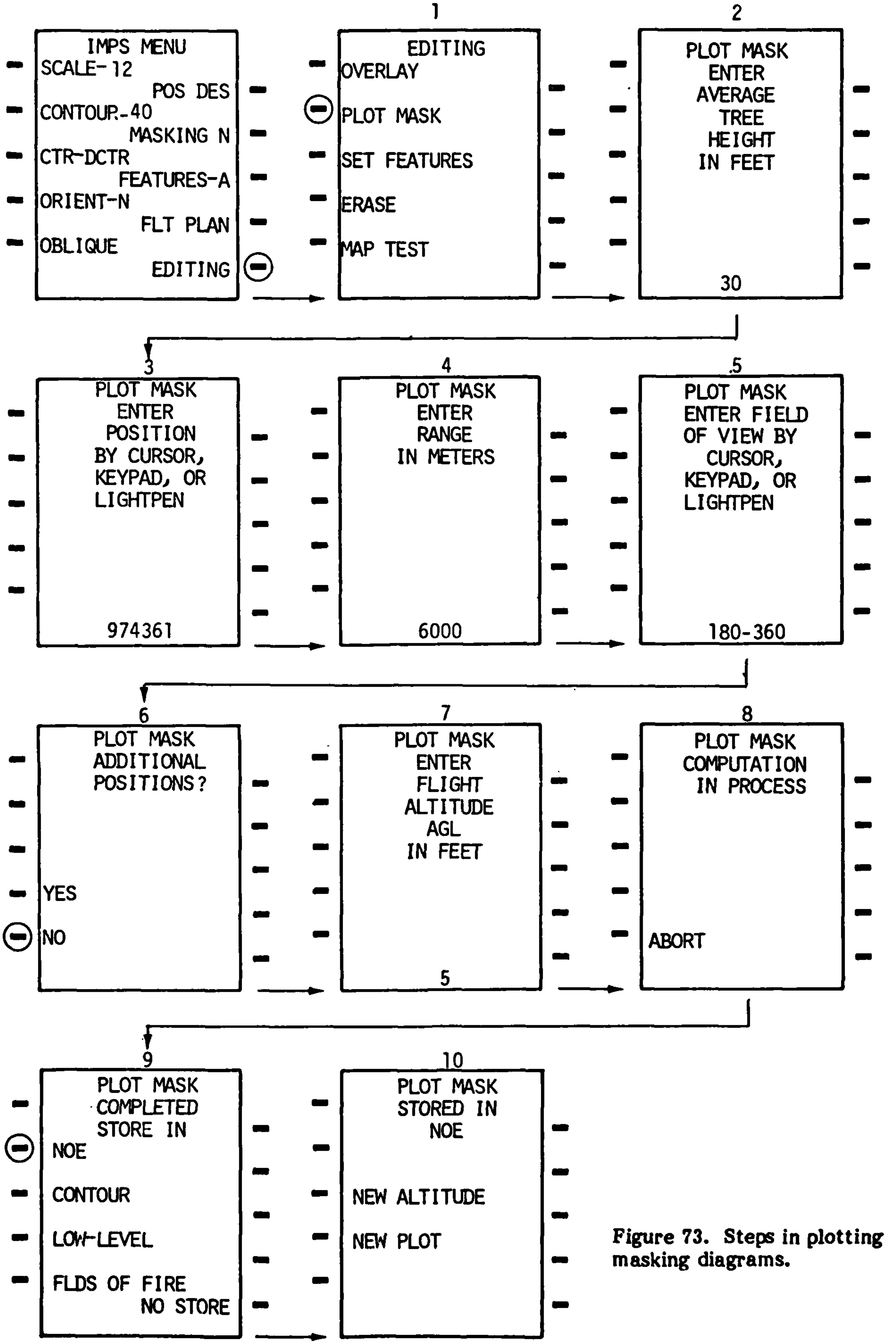

Figure 73. Steps in plotting masking diagrams.

The NO STORE key is useful when the operator is experimenting with other masking computations, such as determining fields of fire for selection of kill zones and firing positions. When it is desirable to save such plots for further study, the FLDS OF FIRE key provides this option.

Page 10 indicates that the NOE storage command has been received and acted upon, and presents the operator with two options. Pressing the NEW ALTITUDE key presents page 7 so that masking diagrams may be plotted for contour and low-level altitudes, using the same enemy sensor/weapon data. If other data are to be used, the NEW PLOT key may be used to return to page 2 in the sequence.

Insertion of tactical features. In addition to the entry of tactical data by the overlay method, individual features may be entered by coordinates, cursor, or light pen. These options are selected by pressing the SET FEATURES key of the editing page, as shown in Figure 74. The CDU then requests the code for the feature symbol to be entered (page 2). Presently existing acronyms are used as codes whenever possible. The operator may page through a list of the possible codes by pressing the DISPLAY CODES key, and use the line select keys to enter the desired feature code. Normally, however, the operator uses the keyboard to enter the code. Page 3 instructs the operator that he may enter the FARRP symbol by keying in its coordinates, or by marking the desired position with the cursor or the light pen. Erroneous entries may be deleted by pressing the ERASE key. The operator can continue to enter this symbol code at as many points as desired. When he wishes to enter another type of symbol, he presses the NEW FEATURE key. In the example, the new feature selected, a FEBA, is a linear feature instead of a point feature. Linear features may be entered in several different ways, as shown in page 5. In the point-to-point method, selected by the PT TO PT key, the operator designates two points on the map display, and a line is drawn between them. The rubber-band method causes the line to appear to stretch between the first point and the cursor or light pen until a second position-indicating signal is entered. The rubber-band method is useful for determining how the line will look, and what other data it will overlap, before it is entered.

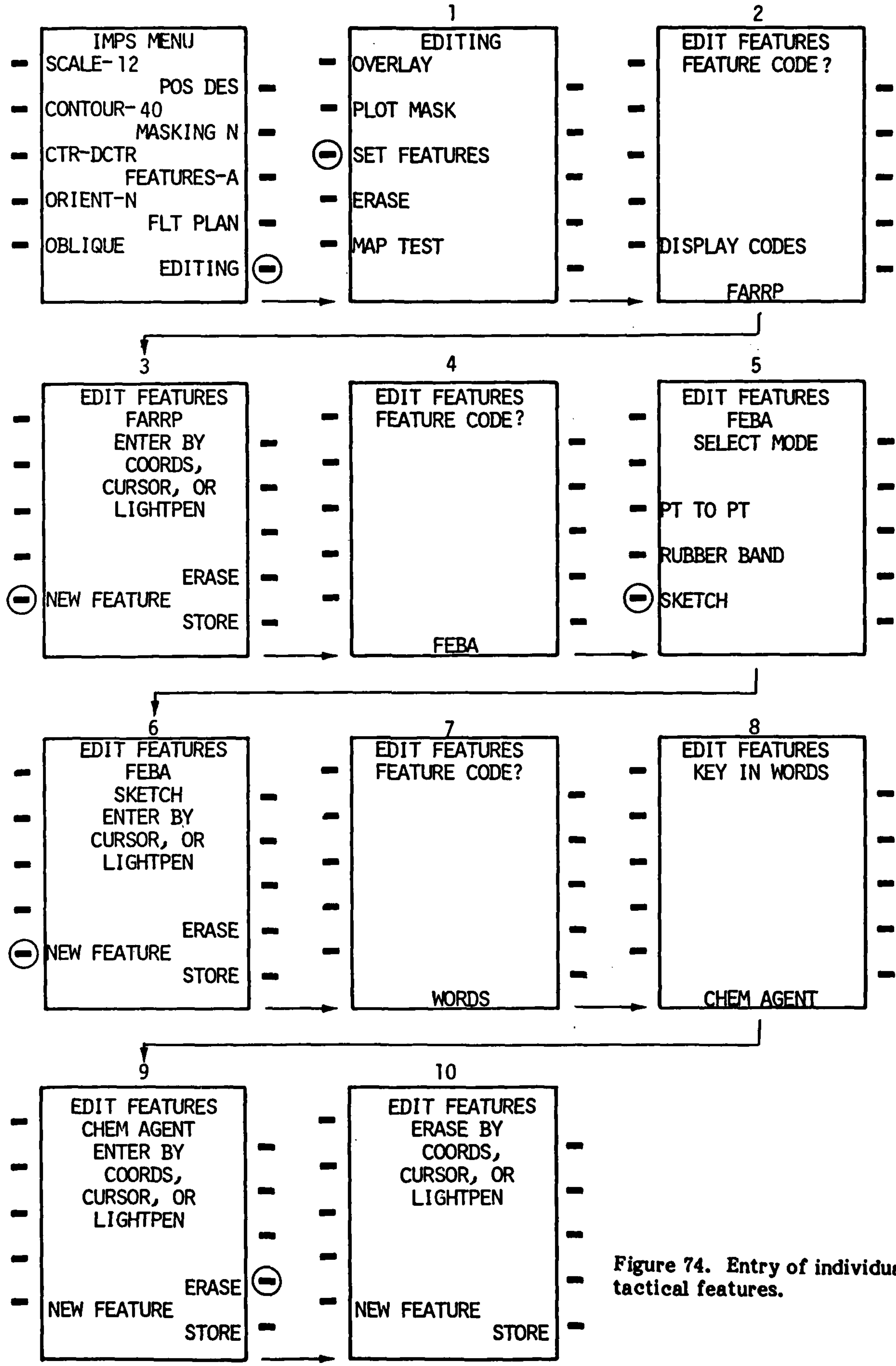

Figure 74. Entry of individual tactical features.

Pressing the SKETCH key permits lines to be drawn in a freehand fashion using the light pen--an exceptionally direct and natural data-entry method. The point-to-point, rubberband, and sketch methods can be exercised using either the light pen or the joystick and cursor.

In addition to point and linear features, the editing system permits the entry of area features and words. Area features are entered in the same manner as linear features, using lines to circumscribe the designated area. Words may be useful for warnings, descriptors, or other advisory data. As shown in pages 7, 8, and 9, words may be entered via the keyboard and positioned by coordinates, cursor, or light pen. Pages 9 and 10 show the method of erasing specific features. The ERASE key is pressed, and the subsequent entries of coordinates or positioning of the cursor or light pen cause the indicated feature to be deleted. When the feature editing has been completed to the operator's satisfaction, the data are recorded on the master tape by pressing the STORE key.

When the battlefield situation is changing rapidly, erasure of tactical features on an item-by-item basis may prove to be too time consuming. For this reason, the editing page provides a special method for deletion of multiple features. As shown in Figure 75, pressing the ERASE key calls a list of erasure options (page 2). The operator may choose to delete all tactical features, general categories of features, specific feature codes, or individual features. In the example in Figure 75, the operator has selected the CATEGORIES key and is presented with a list of general categories of tactical features (page 3). In order to prevent a major loss of data from a momentary lapse in judgment, the CDU instructs the operator (page 4) to key in the erasure command on the keyboard before the system will perform the deletion. The same precautionary method is employed with the request for erasure of all tactical data. Feature symbols are deleted in a manner similar to their entry--by keying in their codes or by paging through a list and pressing line select keys. The ITEM BY ITEM key of Figure 75 provides the same erasure options as described in the feature editing mode previously discussed.

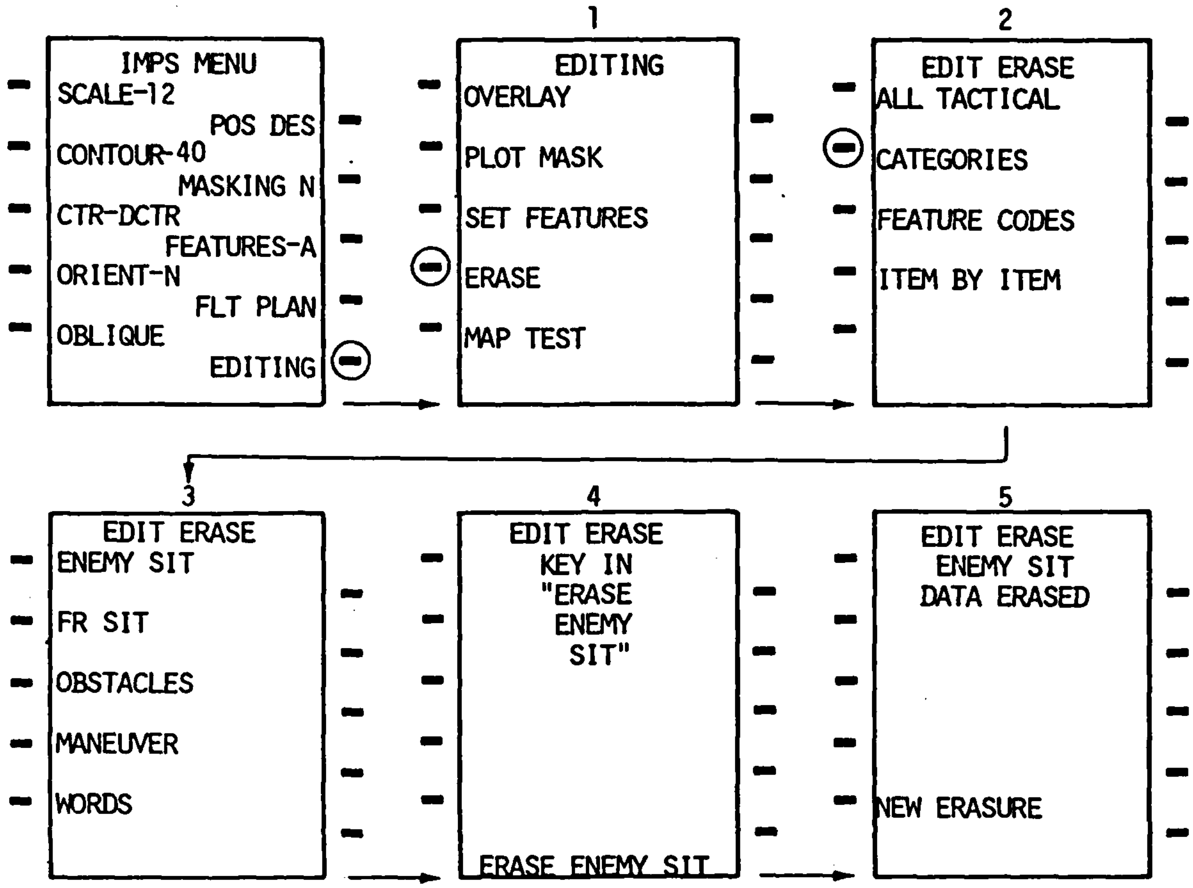

Figure 75. Deletion of multiple tactical features.

FLIGHT PLANNING

Requirements. Following the operations (G3/S3) and intelligence (G2/S2) briefing, the aviator selects and plots LZ's, ambushes and/or firing positions, ACP's, flight routes, potentially hazardous points or areas, key terrain features, and other items of importance to the mission. The special considerations for route selection and annotations have been previously discussed.

The aviator must perform a map reconnaissance, studying the map (and aerial photos, if available) until he is able to visualize the entire route of flight. He must identify areas where detection must be expected because sufficient masking is not available, even at NOE flight levels, and plan for suppressive fires, smoke, chaff, or standoff jamming. The flexibility of mission conduct is in direct

proportion to planning efforts, and extensive planning requires detailed map annotations. The ability to mark, draw, and write upon the map provides an unsurpassed aid in recalling the information noted during the planning process.

Present deficiencies. As noted previously, paper maps are easily annotated, but pencil lines may obscure important topographic data, grease pencil annotations are easily smeared, and acetate overlays mey be difficult to keep in position.

IMPS capabilities. Like the airborne CGTD, the IMPS can compute the range and bearing of ACP's from any point on the map, and can compute the time required to arrive at an ACP at a selected speed, or the speed required to arrive within a given time period. The IMPS also aids the aviator in his planning by computing special masking plots and constructing oblique views of the terrain, both discussed elsewhere in this subsection of the report. In addition, the IMPS can provide annotation capabilities similar to (and in some respects better than) those currently used on paper maps. The aviator can rapidly insert point symbols of his choosing, use a light pen to "draw" linear and area features of importance to the mission, and key in words when special notations are required. In the aircraft, these annotations may be selected or deleted at the touch of a line select key, so that data obscuration or smearing is no longer a problem.

Furthermore, the IMPS permits the aviator to view a simulated real-time depiction of the map display as it would appear during flight along a designated path. This capability is useful in verifying the correct entry of mission-planning data, as well as in "rehearsing" the mission and briefing crews.

CDU operation. When the IMPS MENU page is displayed, pressing the line select key labeled FLT PLAN calls the flight plan options page, as shown in Figure 76. This page provides three options to the aviator. He may initiate a real-time flight simulation, discussed in the following pages, he may annotate the map using the same methods provided in the aircraft (AIR EQUIV), or he may use the more flexible entry methods provided by the IMPS pre-flight annotation. Pressing the IMPS MODE key calls the IMPS flight planning page. This page permits selection of editing and annotating features dedicated to use by an aviator preparing his map for a specific mission. If he wishes, he may choose to use the ENTER PTS or

ENTER LINES keys, and perform the subsequent operations just as they would be performed in the aircraft, except that the light pen, as well as the joystick, is available for point indication. In addition, he may enter words or smoothly curved lines. To enter smoothly curved lines, the aviator presses the SKETCH key, as shown in Figure 76. The CDU then instructs the aviator to sketch either by light pen or by joystick and cursor. The line select keys on this page permit the aviator to slew the map, to erase or store annotation data, and to switch to the entry of point symbols or words. Pressing the line select key labeled FLT PATH on the IMPS flight planning page results in the same capabilities as those provided when the SKETCH key is pressed, but codes the entries as flight path data so that they are appropriately color-coded, and identified for use in the flight simulation mode.

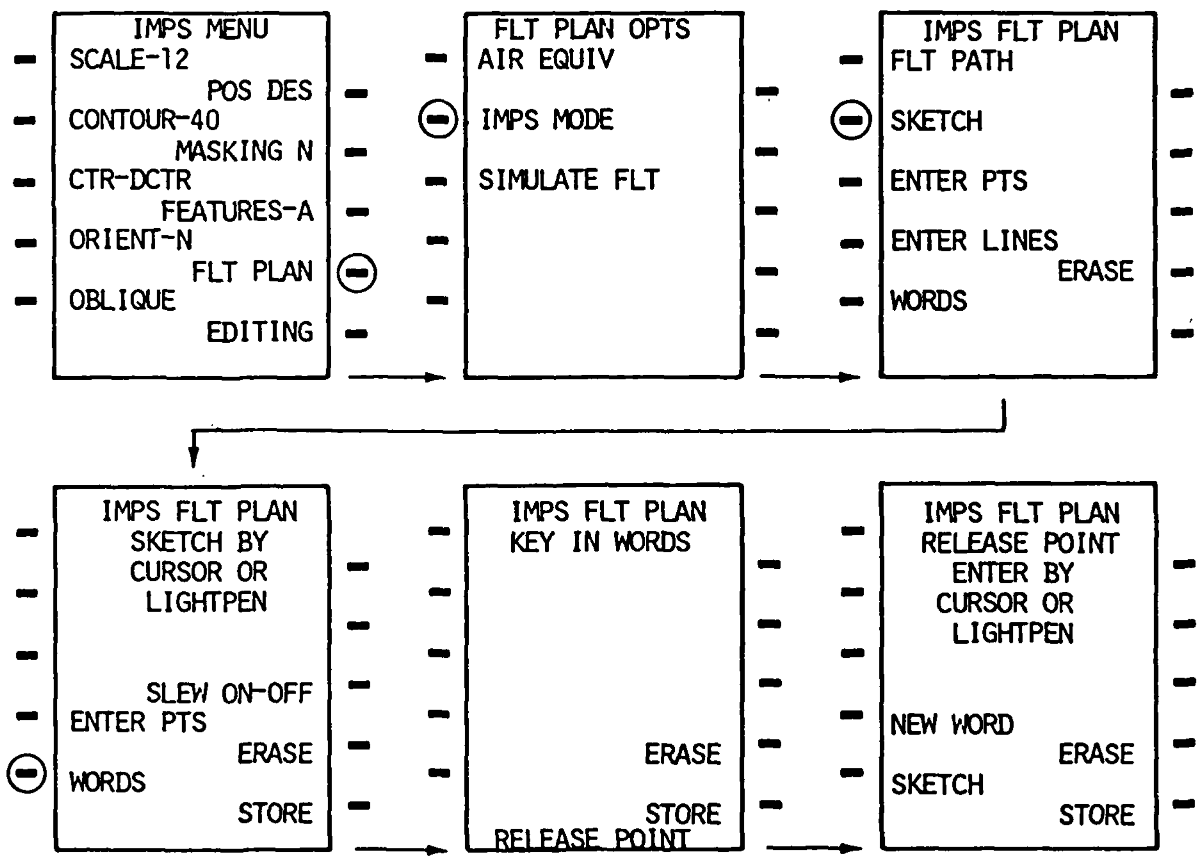

Figure 76. Flight planning options and annotation methods.

Figure 76 also shows the selection of the word entry feature, which is similar to that employed during editing. The required words are keyed in on the keyboard, and positioned by the light pen or cursor.

Flight simulation. A flight simulation is initiated by pressing the line select key labeled SIMULATE FLT on the flight plan options page, as shown in Figure 77. The CDU first requests that the ground speed for the simulation be entered, and then that the simulation mode be selected. The aviator may choose to simulate direct flights between consecutive ACP's (ACP TO ACP). Alternately, the aviator may wish to simulate the aircraft's flight along a smoothly curved line previously entered by cursor or light pen (FOLLOW PATH). Finally, the aviator may wish to use the joystick control to manually direct the course of the aircraft during the simulation (MANUAL CONT). After the simulation mode is selected, the CDU requests the aviator to designate the starting point on the map by coordinates, cursor, or light pen. Following this designation, the final page of Figure 77 appears, permitting the aviator to start the simulation, to pause at any time, to enter a revised flight speed, or to abort the simulation. Once a flight simulation has begun, the CDU system operates almost exactly as if the system were in flight. For example, the various orientation features may be selected, the air-equivalent flight plan page gives range and bearing to ACP's, and the center-decenter selection becomes operational. During such a simulation, pressing the SIMULATE FLT key on the flight plan options page calls the last page of Figure 77, so that the aviator may temporarily or permanently stop the simulation (by pressing PAUSE or ABORT), or change the groundspeed. The currently selected groundspeed is indicated in the lower portion of the CDU screen.

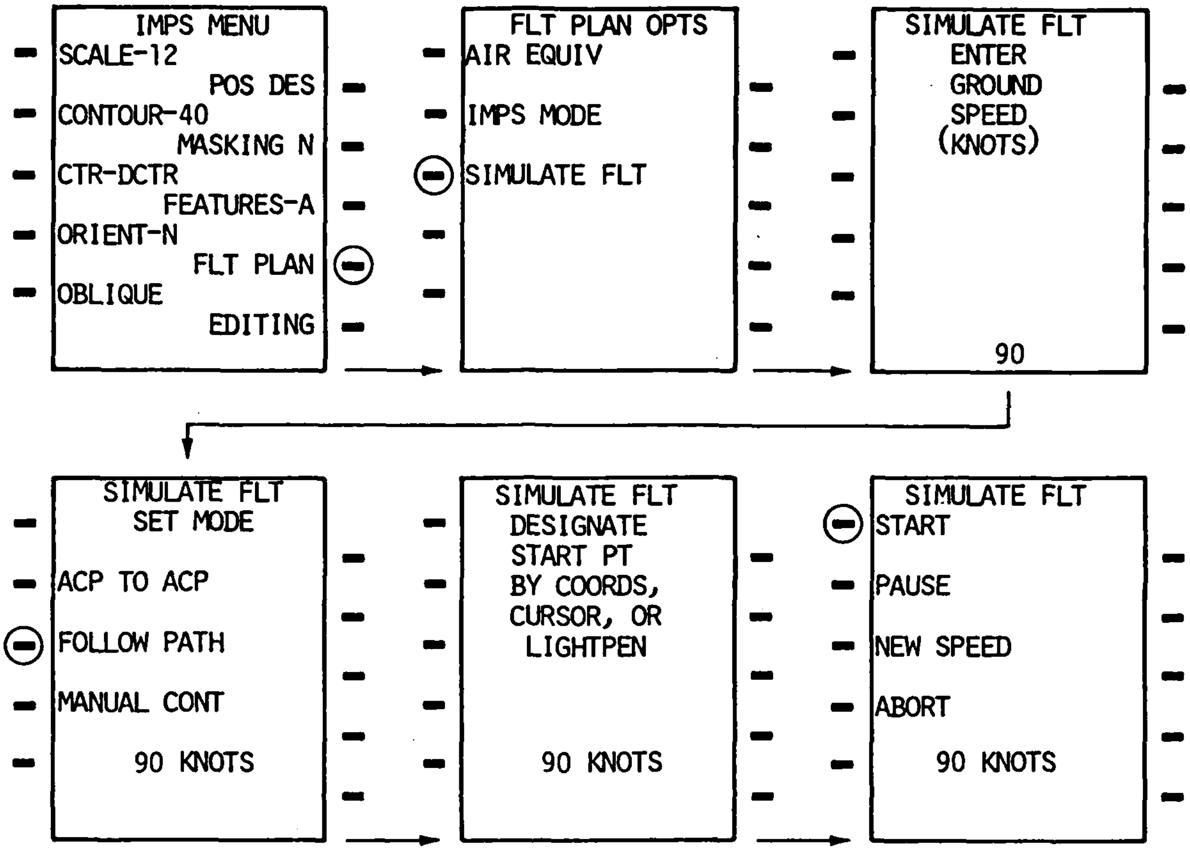

Figure 77. Employment of the flight simulation feature.

OBLIQUE VIEW CONSTRUCTION

Requirements. An oblique view of the terrain is one which portrays the terrain as it might be seen from some angle between ground level and directly overhead. The virtue of oblique photographs is that they present terrain from a more familiar point of regard than that provided by the vertical view, and features are usually more recognizable. In particular, terrain relief becomes much more discernible in an oblique view than in a vertical view.

The preflight uses of the oblique view included its employment in route selection, tactical decision-making, and route rehearsal. The oblique view simplifies the specification of good checkpoints, barrier features, battle positions, landing zones and many other such terrain-related mission-planning requirements.

Examination of the features as portrayed by the oblique view offers the aviator an opportunity to develop an "area familiarity" without exposing him to the unacceptable risk of flight hundreds of feet above the actual terrain in a high-threat environment.

Present deficiencies. An important disadvantage of oblique photographs is that they cannot be used to determine distances between features. Since photographs present a perspective ("vanishing point") view of terrain, their scale is not constant. In addition, because of the risk and the time requirements involved in obtaining a sufficient number of oblique photographs to adequately cover an area of operations, they are unlikely to be available to Army aviators.

CGTD capabilities. A computer-generated topographic display system can, in many respects, substitute for oblique view photography. In other respects, computer-generated visualizations are superior to photographic imagery. With the IMPS system, the aviator need not search for or request specific aerial photographs, but can select exactly the views he needs to examine the terrain--either from well above ground level, or from NOE altitude. Such a system may be employed to construct a perspective view of the landforms, as they might appear to the human eye, either at ground level, or at any chosen elevation above the terrain (see Figure 78). Another kind of oblique view can be constructed by a computer-generated topographic display: the isometric projection. This kind of oblique view is unlike a photograph because it does not employ vanishing-point perspective. Instead, ground distances are kept proportional and constant, as in an engineering drawing used for shop measurements. In this manner, three-dimensional landforms may be portrayed, yet distances may be measured between points--a significant advantage in flight planning and tactical decision-making (see Figure 79).

CDU operation. When the IMPS MENU page is displayed, pressing the line select key labeled OBLIQUE initiates the steps required for oblique view construction, as shown in Figure 80. The operator enters the position from which the view is desired, the direction of the view, and the altitude above ground level from which the view is to be computed (pages 1, 2, and 3). Next, the operator chooses

Figure 78. A computer-generated perspective view of terrain.

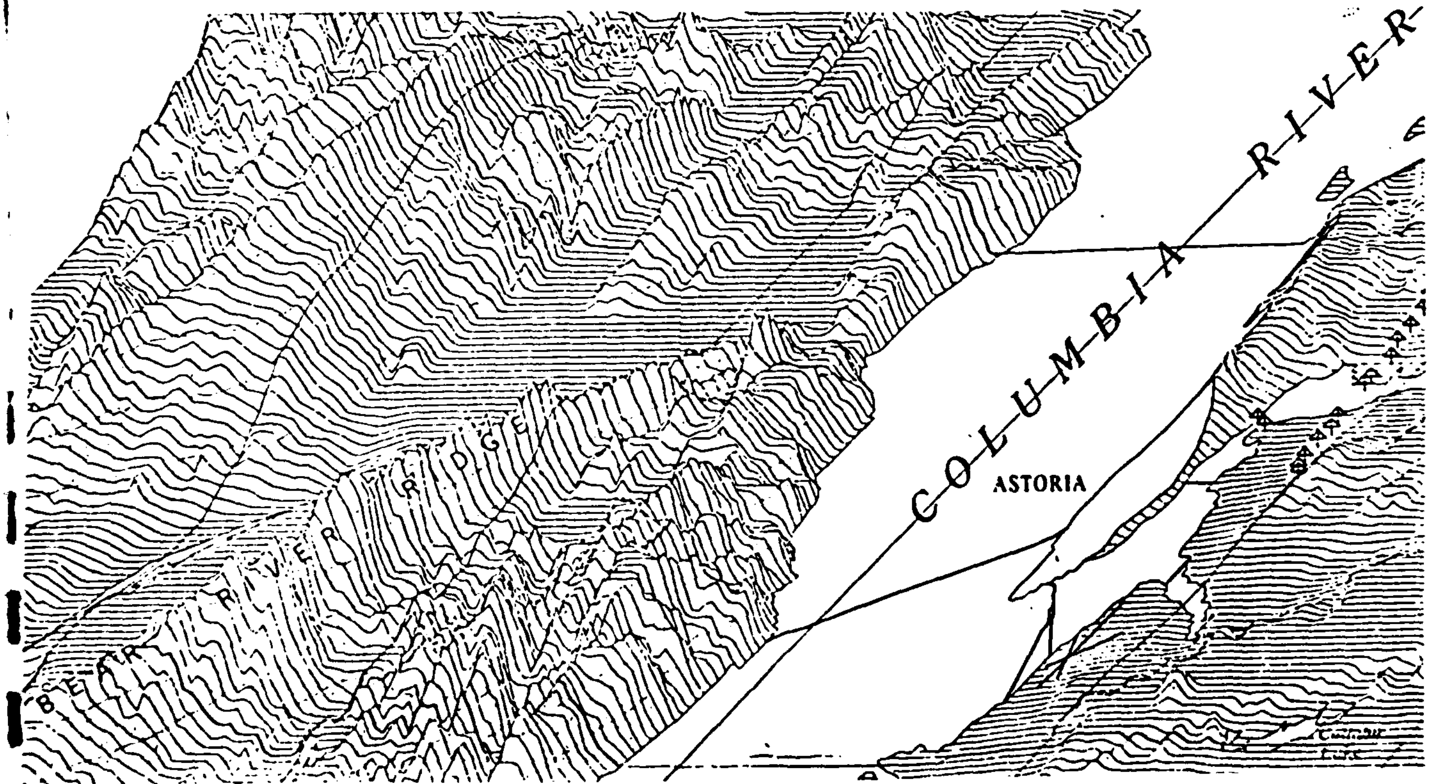

Figure 79. A computer-generated isometric projection of terrain.

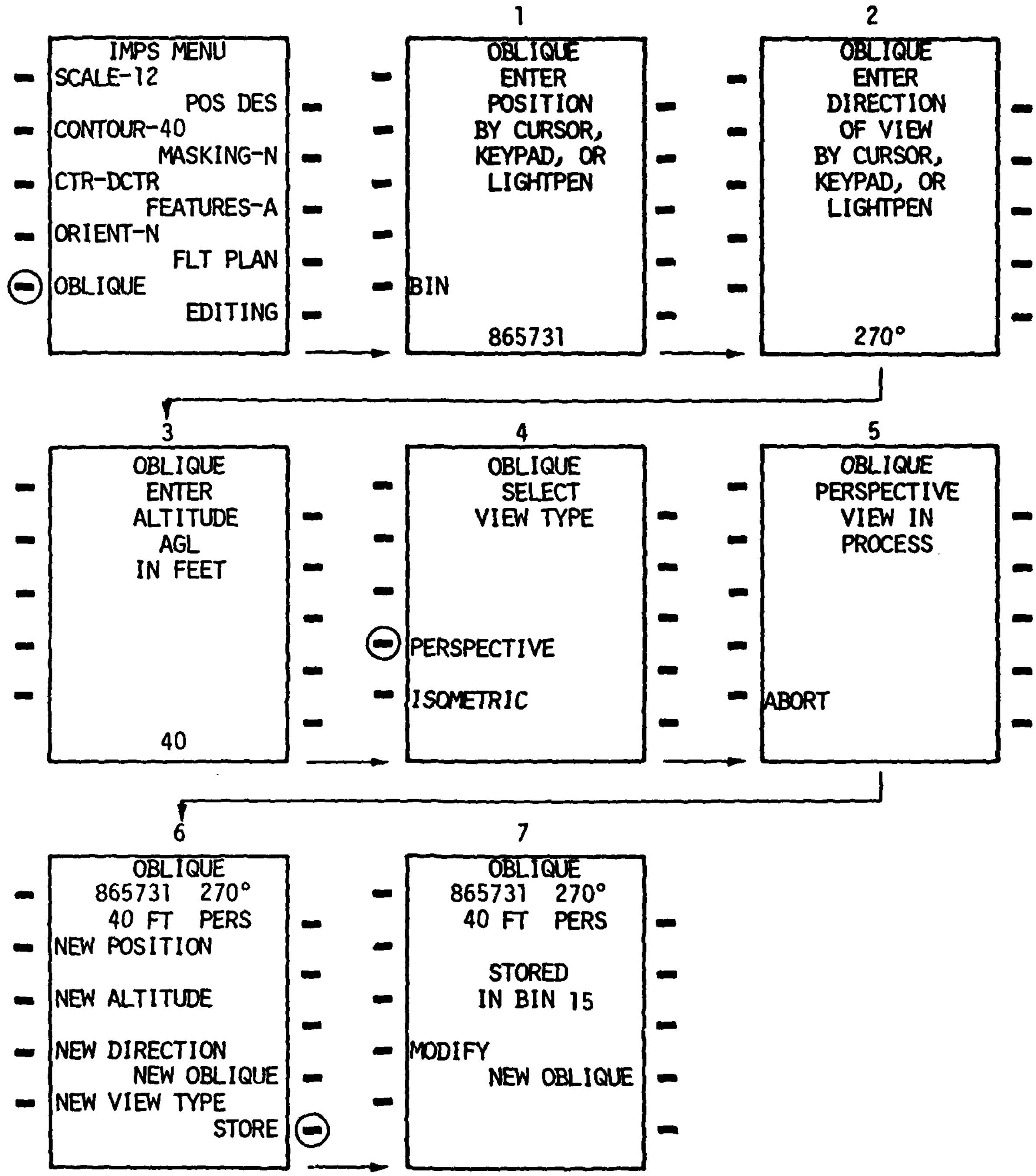

Figure 80. Construction of an oblique view.

between the perspective and isometric view types, and the system begins to construct the view. An ABORT key is provided in case the IMPS system is urgently needed for other purposes (page 5). When the view is completed, the CDU displays the position, direction of view, altitude, and view type (page 6) and permits the aviator to alter any one of these variables for the construction of additional views. If more than one variable is to be changed, the NEW OBLIQUE key is pressed to return to Page 1 in the sequence. When the desired views are achieved, the operator may elect to save them for later use. This is done by pressing the STORE key. The CDU then indicates the retrieval code ("Bin 15" in the example) and provides a NEW OBLIQUE key as well as a MODIFY key to call Page 6 for alteration of any of the view variables. Stored views are recalled by pressing the line select key labeled BIN on Page 1 and entering the desired retrieval code.

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APPENDIX A

SURVEY OF POTENTIAL USERS OF COMPUTER-GENERATED MAP DISPLAYS

OBJECTIVES

The main objectives of the survey of potential users of a computer-generated topographic display (CGTD) were: (1) to identify current practices with paper maps that might influence the design of a CGTD, (2) to examine opinions of Army aviators regarding basic requirements for such a system, and (3) to study pilots' opinions of various special features and functions of a CGTD.

SURVEY SAMPLE

Thirteen experienced Army aviators from the 101st Airborne Division (Fort Campbell, Kentucky) participated in the survey. These aviators had a collective 26,000 hours of flight experience in one or more types of aircraft--including aero-scout, utility, and attack helicopters. None of these aviators had any experience with either a computer-generated or an optically-projected map display system. Nine had flown an aircraft equipped with a doppler navigation system.

METHOD

The basic survey instrument was a questionnaire designed to interrogate the aviators regarding their assessments of map information requirements, and their opinions about potentially useful features of interactive, computer-generated maps. In order to focus each aviator's attention upon the factors of particular concern (and to gather additional data), individual pilots were interviewed for approximately two hours prior to the administration of the questionnaire. The interviews dealt with the considerations involved in the planning and conduct of missions in a high-threat environment. In order to avoid very broad, general questions (likely to result in vague or irrelevant answers), a 1:50,000-scale military topographic map was studied and annotated by the aviator, simulating the procedures that he would use in a combat situation.

The last portion of the interview was devoted to briefing the aviator on the nature of the CGTD concept, and describing some of the potential capabilities of such a system. The aviators, without exception, greeted the concept with enthusiasm and often suggested potentially valuable system capabilities for consideration. The interview was concluded with the distribution of the questionnaire. The data collected in this manner are provided below in tabular form. Each item presents the question directed to the aviators and a summary of their responses. The data are summarized by simple counts of response categories, by mean averages, and by listing specific written comments. The comments of the aviators, and of the author, are printed in italic type.

SURVEY RESPONSE RESULTS

1. What is your estimated total number of helicopter flight hours?

   Mean, 2012 hours. Range, 400-5200 hours.

2. What is your estimated total number of nap-of-the-earth flight hours?

   Mean, 539 hours. Range 200-2500 hours.

3. In what helicopter aircraft are you qualified?

OH-58 (8)	OH-13 (2)	OH-23 (2)
UH-1H (13)	UH-60A (5)	UH-19 (1)
AH-1G/R (5)	AH-1Q/S (3)	AH-1/S (1)
CH-47C (2)	TH-55 (2)	

4. For **MISSION-PLANNING** purposes, which map scales would offer the greatest utility if you could choose:

ONLY 1	ANY 2	ANY 3	
( )	( )	( )	1:1,000,000
( )	( )	(1)	1:500,000
( )	(4)	(9)	1:250,000
( )	(4)	(6)	1:100,000
(11)	(12)	(12)	1:50,000
(1)	(4)	(8)	1:25,000

5. At any given time during **ENROUTE NAVIGATION**, what is the **MINIMUM** distance ahead that you would want to be able to see on a map display (without slewing the map)?

Mean, 5233 meters.	Range, 200-10,000 meters.
Mean 2.9 minutes.	Range, 0.25-5.00 minutes.

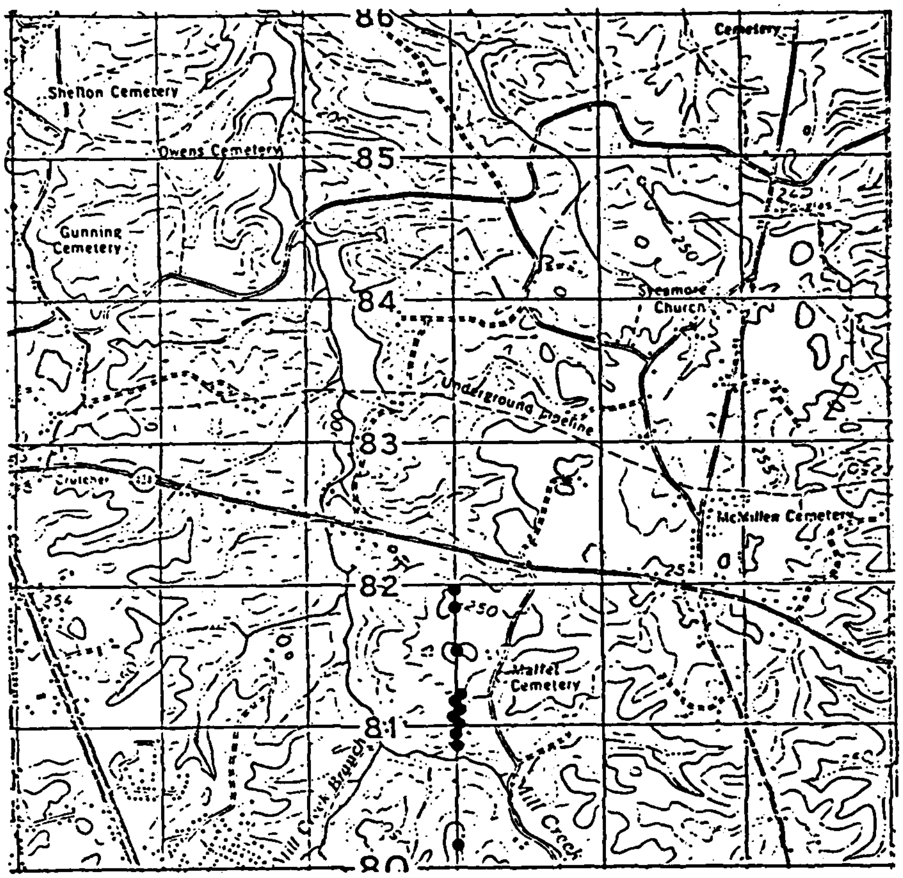
6. As a rule, what is the **MAXIMUM DISTANCE** ahead that you would need to see on a map display (without slewing the map)?

Mean, 14,125 meters.	Range, 1,500-20,000 meters.
Mean, 6.9 minutes.	Range, 1-15 minutes.

7a. Moving-map displays in high-performance aircraft have usually employed two present-position indicators, one at the center of the map, and another decentered to increase look-ahead distance. The centered position indicator leaves half of the map to show what is behind the aircraft. Would this be useful to the Army aviator? NO (6) YES (7) If yes, why?

Aviators indicated that a centered position would be useful in marking by-passed sites, such as downed aircraft, or enemy positions. They also noted that it would provide the ability to consider escape routes to the rear of the aircraft without having to turn the aircraft 180 degrees.

7b. Assume the aircraft is flying due north. Draw an "X" on the map to indicate about where the decentered position-indicator should be located.



To reduce clutter, the center positions of the X's are shown by dots in this figure. The mean choice was 1,168 meters from the bottom of the map segment (range 150-1950 meters).

7c. Draw the kind of a symbol that should be used to indicate the aircraft's position on the map.

It appears that there is little agreement on the shape appropriate for a present-position indicator.

8. A computer-generated map display would normally be oriented with the wind corrected track up at all times. If words, numbers, and symbols are always shown right-side up, regardless of the direction of flight, is there any need for a "North-up" mode in addition to the "Track-up" mode? NO (10) YES (3) If so, what?

Two aviators believed that a North-up mode might help prevent disorientation in some cases, such as circling approaches or go-arounds. Another pointed out that for in-cockpit planning activities it would be useful to be able to turn the map to any cardinal direction without having to change the aircraft heading--especially if the aircraft is on the ground.

9. Prior to the flight, the aviator would be able to annotate the map with his planned course. Would a record of the path actually flown serve any purpose? NO (8) YES (5) If yes, what purpose?

Several of the aviators felt that such a feature might sometimes be useful if the pilot wished to return by the same route. Others suggested it would help in debriefings. One aviator noted that a record of the path might be useful in training. This feature would be likely to encounter user-acceptance problems since several of the aviators who said "no" indicated that they did not want their peers or superiors to see exactly where they had flown.

10. Cassettes will be used to store digital data for each mapped area. Cassettes will be changed when flying from one area to another. How much overlap should be provided between these areas?

Mean, 4000 meters. Range, 1000-5000 meters.

11. Unlike a paper map, a computer-generated map might not have a legend or marginal information. Which of these items should be displayed?

	Continuously	On Demand	Never (unnecessary)
MAP SCALE	(3)	(11)	( )
CONTOUR INTERVAL	(5)	(8)	( )
ADJOINING SHEETS	( )	(11)	(2)
ELEVATION GUIDE	( )	(13)	( )
DEFINITON OF SYMBOLS	( )	(9)	(4)
OTHER *(ADA THREAT)*	(3)	( )	( )

12. Even though the aircraft's position on the map is visible, should the aircraft's present coordinates also be displayed at all times?
Yes __(2)__ On demand? __(11)__

13. When the scale of the map is changed during flight, what information should be indicated to the aviator?

The map scale (1:50,000, 1:100,000, etc.) (6)
or, ground distance shown (6 km, 12 km, etc.) (7)

Several of the aviators indicated that if grid squares are not shown on the map, some supplementary method must be incorporated to aid the aviator in making judgments of distance.

14. When communicating geographic positions by radio, what system do you use:

Simple coordinates	(10)	*(Enemy positions only)*
Coded coordinates	(9)	
"Thrust lines"	(2)	
Predesignated code words	(11)	
Range & Bearing from known position	(8)	

15. Do you usually put time or distance tic marks on your planned courseline? NO (8) YES (4) If yes, how far apart?

1 minute (2) 30 seconds (1)

1 km (1) 1.5 km (1) 5 km (1)

Two of the aviators noted that time tic marks were particularly useful in night flight.

16. For efficient operations, how large an area of coverage should be available on a computer-generated map tape cassette?

100 x 100 km (4)

50 x 50 km (1)

Only five responses are shown here because several of the aviators misunderstood the intent of this question and responded inappropriately.

17. It would be possible for the map display to continuously compute range and bearing to the next ACP or to the objective. Would this information be useful in an NOE flight mode? NO (1) YES (12) Why?

Nearly all aviators agreed that this would be a very useful function for one or more of the following reasons:

- *As an aid to orientation, especially at night or in limited visibility.*
- *For direct flight to objectives if arrival times are critical and deviations from the planned route are mandatory.*
- *To remind pilots of required actions at pre-briefed points, such as formation changes, radio calls, etc.*
- *For immediate planning purposes and mental computations of required flight speeds.*
- *For communication of plans to ground personnel or supporting aircraft.*
- *To keep the pilot's head "out of the cockpit," enhancing his flying ability.*